A mixture of 2.30 g (0.01 mole) of the chloride and 1.30 g (0.01 mole) of VII in 25 ml of anhydrous ethanol[20] was shaken at ambient temperature for 48 hr. Anhydrous ethanol (100 ml) was added and the mixture was gently warmed until all crystalline material had dissolved; 25 ml of water was added and the product was allowed to crystallize slowly at 0°. The bright yellow needles of Xb (2.6 g, 80%) were filtered, washed, and dried, mp 90–92.5°.

When active alcohol VII was used, the product had the same melting point range but showed $[\alpha]D$ +36°, (*c* 0.1, chloroform). A mixture melting point of the active and inactive Xb showed the same melting point range. The pmr data (chloroform solution, internal TMS) were as follows: 1.50 (doublet, J = 2.5 cps, 1 proton), 1.6 (doublet of doublets, J = 2.5, 9 cps, 1 proton), 2.3 (doublet, J = 9 cps, 1 proton), 3.52 (doublet, J = 2 cps, 1 proton), 5.75 (quartet of doublets, J = 2,7 cps, 1 proton), 6.4 (AB quartet, J = 8, 4, 8 cps, 2 protons), 8.65 (doublet, J = 7 cps, 3 protons), 8.84 (singlet, 6 protons).

Anal. Calcd for $C_{14}H_{16}SN_2O_5$: C, 51.84; H, 4.97. Found: C, 51.76; H, 5.03.

(20) One of the referees has questioned the choice of ethanol as solvent because solvolysis of the 2,4-dinitrobenzenesulfenyl chloride would be expected. We chose this solvent because it gave better yields of the crystalline adduct. Other solvents tried included carbon tetrachloride (16 hr, 25°) and ethylene dichloride containing about 5% of acetic acid (3 hr, 25°); both experiments gave oils which were not successfully crystallized, but which contained mainly Xb on the basis of pmr spectra.

In all of these experiments, hydrogen chloride was detected as a reaction product. However, when 2,4-dinitrobenzenesulfenyl chloride was allowed to stand in ethanol at ambient temperature for 24 hr, no acid fumes were given off. It was not established whether or not some hydrolysis of the chloride occurred, but at least it would appear to be slow compared with the addition.

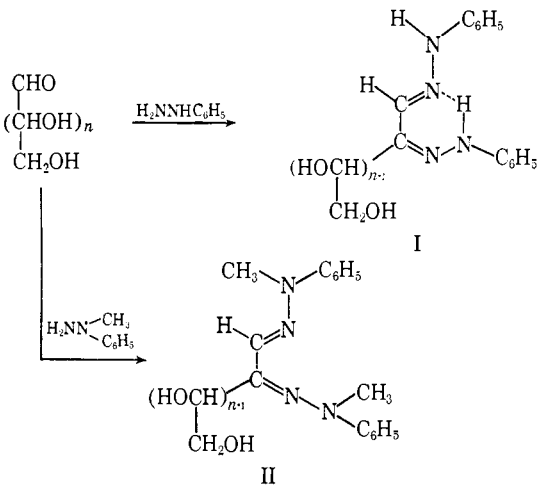
1-Methylphenylhydrazine Oxidation of Sugars. The Alkazones[1]

O. L. Chapman, W. J. Welstead, Jr., T. J. Murphy,[2] and R. W. King

Contribution from the Department of Chemistry, Iowa State University, Ames, Iowa 50010. *Received July 13, 1967*

Abstract: Oxidation of 1,3-dihydroxyacetone, erythrose, arabinose, xylose, and fructose is shown to oxidize all hydroxyl functions in the chain in each case giving rise to a new class of compounds for which the name alkazone is suggested. The yield of the alkazone decreases with increasing chain length. In each case a single crystalline alkazone is obtained. The same alkazone is obtained from the stereoisomeric sugars arabinose and xylose. The observed oxidation is consistent with but does not require the Fieser hypothesis that chelate formation is the factor which limits phenylhydrazine oxidation of sugars to osazone formation. Arguments are presented which suggest that chelate formation may not be the factor which limits phenylhydrazine oxidation of sugars.

Fischer's classic study[3] of the phenylhydrazine oxidation of sugars demonstrated that oxidation was limited to osazone formation, *i.e.*, only the hydroxyl function adjacent the carbonyl function was oxidized. It has been suggested[4] that the failure of phenylhydrazine to oxidize sugars further down the chain is associated with chelate formation in the osazone (I). This suggestion has been widely quoted and generally accepted in organic chemistry text books. If chelate formation is the factor responsible for preventing further oxidation, 1-alkylphenylhydrazines would be expected to oxidize down the chain since chelate formation is not possible with alkylphenylosazones (II). This is an obvious corollary of the Fieser chelate hypothesis, but no mention is made of it in discussions of this topic. This omission takes on significance when one reviews the literature of 1-alkylphenylhydrazine oxidation of simple sugars. Only alkylphenylosazones are reported. Furthermore, the logical inconsistency between the explanation given for limitation of phenylhydrazine oxidation and the observation of similarly limited oxidation of sugars by 1-methylphenylhydrazine does not seem to have attracted attention. This inconsistency prompted the present investigation of 1-methylphenylhydrazine oxidation of simple sugars.



I

II

Examination of the literature reveals reports of two methylphenylosazones from 1,3-dihydroxyacetone (or its isomer glyceraldehyde) and one methylphenylosazone each from erythrose, arabinose, xylose, and fructose.[5] The report of two methylphenylosazones (mp

(1) A preliminary account of this work has been published: O. L. Chapman, W. J. Welstead, Jr., T. J. Murphy, and R. W. King, *J. Am. Chem. Soc.*, 86, 732 (1964).

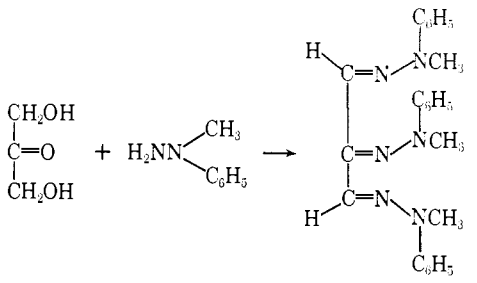
(2) National Institutes of Health Predoctoral Fellow, 1965–1967.

(3) E. Fischer, *Ber.*, 17, 579 (1884); 20, 821 (1887).

(4) L. F. Fieser and M. Fieser, "Organic Chemistry," 2nd ed, D. C. Heath and Co., Boston, Mass., 1950, pp 369–372.

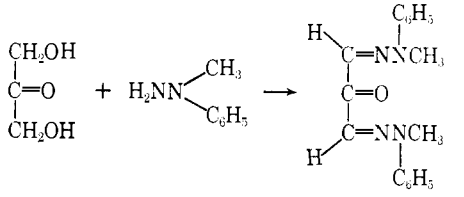
(5) Other methylphenylosazones are known. These are mentioned because the oxidation of each of these by 1-methylphenylhydrazine has been studied in the present work.

127–130° and 147–148°)[6,7] for 1,3-dihydroxyacetone was particularly interesting, since crystallization of osazones rarely gives two isomers. The experimental evidence for the methylphenylosazones was not convincing. One isomer (mp 127–130°) was characterized[6b] only by melting point and a nitrogen analysis; the other by melting point, complete element analysis,[6a] and formation of the same compound from hydroxypyruvaldehyde and 1-methylphenylhydrazine.[7] We have prepared both compounds and have been led by the spectroscopic properties of these substances to conclude that neither is the methylphenylosazone of glyceraldehyde. Treatment of 1,3-dihydroxyacetone with excess 1-methylphenylhydrazine in water–ethanol–acetic acid solution gave a compound, mp 124.5–127°, in 93% yield. The nmr spectrum of the product showed only two aldimine protons as a singlet at δ 7.62, aromatic protons (15) centered at 7.16, and methyl protons as singlets at 3.37 (3) and 3.24 (6). Element analysis and mass spectrometric molecular weight confirm the introduction of three 1-methylphenylhydrazine units. Formation of III represents the first example of oxidation beyond the osazone stage. The second product (mp 147°) of oxidation of 1,3-dihydroxyacetone was obtained by use of a limited amount of 1-methylphenylhydrazine.



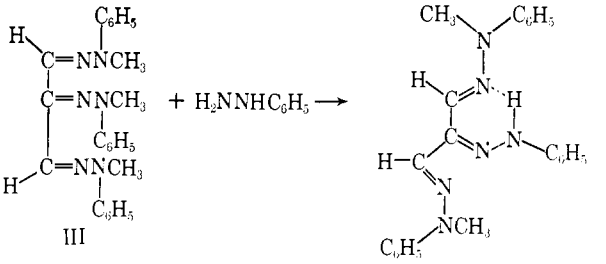
III

This compound showed an aldimine proton at δ 7.63, aromatic protons centered at 7.33, and methyl protons at 3.45 ppm. The area ratios are 1:5:3. The infrared spectrum of this product shows a carbonyl bond at 6.13 μ. These observations together with the absence of resonance attributable to protons on saturated carbon (other than methyl protons) leads to structure IV for the second oxidation product. The formation of IV in the



IV

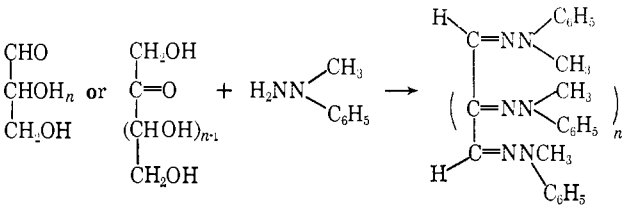
presence of limited amounts of 1-methylphenylhydrazine suggests that the central 1-methylphenylhydrazone unit is the last to form. It is interesting in this regard that the central hydrazone unit of III is the most susceptible to nucleophilic replacement. When III is treated with phenylhydrazine, the C-2 methylphenylhydrazone unit is cleanly replaced by a phenylhydrazone unit giving a chelate structure. The chelate product shows a chelate



III

N–H at δ 12.8, two aldimine protons at δ 8.07 and 7.40, aromatic protons centered at δ 7.23, and two methyl groups at δ 3.32 and 3.40 ppm. The location of the methylphenylhydrazone groups on the terminal carbons was confirmed by a double resonance experiment which demonstrated that each aldimine proton was coupled to one of the N-methyl groups. Irradiation of the aldimine resonance at δ 8.07 collapsed the doublet at δ 3.40 (^5J = 0.6 cps), and irradiation of the aldimine at δ 7.40 collapsed the doublet at δ 3.32 (^5J = 0.5 cps). Control studies have shown (*vide infra*) that aldimines couple only to the N-methyl protons on a terminal methylphenylhydrazone unit.

It could easily be argued that 1,3-dihydroxyacetone is a special case in phenylhydrazine oxidations (although it gives only the phenylosazone with phenylhydrazine). For this reason we investigated the oxidation of erythrose, arabinose, xylose, and fructose. Treatment of each of these sugars with excess 1-methylphenylhydrazine gave the corresponding derivative in which all hydroxy groups had been oxidized. This unique oxidation produces a class of compounds (V) for which we suggest the name alkazone.[8] This name should serve the same useful function as the name osazone. The oxidation involves 1-methylphenylhydrazine which is reduced to ammonia and N-methylaniline. As the chain length of the sugar increases, the yield of the methylphenylalkazone decreases. This decrease is in part due to the



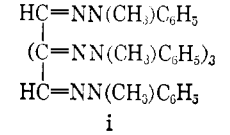
V

longer time required to complete the oxidation of the sugar and the consequent increase in the number of by-products. In the case of fructose, glyoxal bismethylphenylhydrazone is a significant by-product under certain conditions.[9] The methylphenylalkazones crystallized as single isomers in each case. Two crystal forms of methylphenylbutazone have been obtained. Both forms give identical spectra in solution. The nmr spec-

(6) (a) F. Chick, *Biochem. Z.*, 40, 481 (1912); (b) C. Neuberg, *Ber.*, 35, 959 (1902).

(7) H. P. den Otter, *Rec. Trav. Chim.*, 56, 474 (1937).

(8) The term alkazone is intended as a general term for this class of compounds just as osazone is used for that class of compounds. The chain length of the alkazone may be specified in the name together with an identification of the hydrazone unit. As an example, i is methylphenylpentazone.



i

(9) Cleavage of sugars to two-carbon fragments is reasonable.[10]

(10) R. Breslow, *Tetrahedron Letters*, No. 21, 22 (1959).

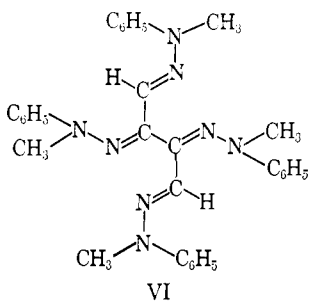
Table I. Properties of the Methylphenylalkazones

Source	Alkazones	Bp (mm) or mp, °C	Alkazone yield, %	Mass spectrometric parent ion (% base)[a]	$\lambda_{max}^{95\%EtOH}$, mμ (ε)
	Methylphenylmethazone	114–115 (15)			273 (19,300), 231 (4800, sh)
	Methylphenylethazone	216–220[b]			359 (29,000), 307 (5000, sh), 241 (5600, sh), 217 (10,300, sh)
1,3-Dihydroxyacetone	Methylphenylpropazone	124.5–127	93	398 (61)	373 (24,000), 339 (24,500), 255 (24,500)
Erythrose	Methylphenylbutazone	149–151 158–160 (polymorphs)	72	530 (5.2)	357 (52,900), 307 (21,500, sh), 242 (23,900, sh), 220 (26,200, sh)
Arabinose, xylose	Methylphenylpentazone	150–152	30 39	662 (0.023)	360 (41,000), 289 (27,900, sh), 251 (41,000)
Fructose	Methylphenylhexazone	262–264	2	...	358 (61,000), 295 (24,000, sh), 234 (23,000, sh), 222 (28,800)

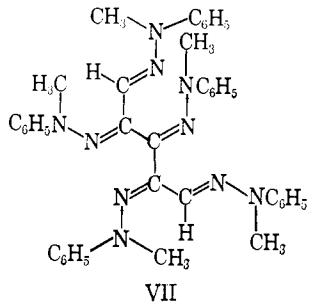
[a] Mass spectra were obtained with an Atlas CH-4 mass spectrometer using the TO4 ion source. [b] The high melting point of methylphenylethazone is surprising, but the solution spectra of this compound are closely analogous to those of the other alkazones.

tra of the alkazones (Table II) showed only aldimine protons, aromatic protons, and methyl protons in accord with the assigned structures. Other evidence which supports the assigned structures is the absence of hydroxyl and carbonyl absorption in the infrared spectra, the element analyses, and the mass spectrometric molecular weights (no parent ion was observed with methylphenylhexazone).

Stereochemical problems increase rapidly with increasing chain length. These problems are reflected in both the ultraviolet spectra (Table I) and the nmr spectra (Table II). In the methylphenylalkazone (methylphenylbutazone) derived from erythrose the nmr spectrum shows identical aldimine protons and two sets of methyl groups. The molecule thus must have a center of symmetry. This suggests VI as the most likely geometric isomer. In the nmr spectrum of methylphenyl-



VI



VII

pentazone (derived from the aldopentoses) the two aldimine protons are not equivalent, and four different methyl resonances are observed (the coincidence of two of the resonances is fortuitous) as expected since the molecule cannot have a center of symmetry.[11] A spin-decoupling experiment in which both aldimine protons were irradiated sharpened the two terminal N-methyl resonances sufficiently to permit observation of five

(11) Methylphenylpropazone shows equivalent aldimine protons and terminal N-methyl protons. This is probably due to the substantially greater flexibility in the C-3 chain as opposed to the C-5 alkazone chain in which steric problems are severe.

Table II. Nuclear Magnetic Resonance Spectra of the Methylphenylalkazones[a]

Length of carbon chain	Aldimine C–H	Aromatic protons	Methyl protons
1	6.54 (1) 6.59 (1)	7.51 (5)	3.01 (3)
2	7.50 (2)	7.30 (10)	3.37 (3)
3	7.62 (2)	7.16 (15)	3.37 (3) 3.24 (6)
4	7.56 (2)	7.10 (20)	3.44 (6) 3.24 (6)
5	7.67 (1)	7.12 (25)	3.47 (3) 3.34 (3)
	7.50 (1)		3.29 (6) 3.14 (3)
6	7.66 (2)	7.12 (30)	3.65 (6) 3.53 (6) 3.42 (6)

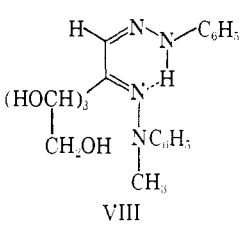
[a] Spectra were obtained on deuteriochloroform solutions using a radiofrequency of 60 Mc. Resonance locations are given as ppm downfield from internal tetramethylsilane. The numbers in parentheses give the number of protons.

nonequivalent N-methyl resonances. The most probable geometry for methylphenylpentazone is VII.

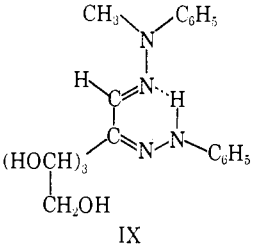
Arabinose and xylose, both aldopentoses, give the same alkazone which is devoid of optical activity. Stereochemical differences in the sugars thus do not affect the nature of the product. The stereochemistry of the alkazone probably is determined by thermodynamic stability.

The aldimine protons in each of the alkazones through methylphenylpentazone couple to the N-methyl protons of the terminal methylphenylhydrazone unit ($^5J \cong 0.9$ cps). This permits identification of the resonances due to these N-methyl groups (III, δ 3.24; VI, δ 3.24; VII, δ 3.29). In methylphenylmethazone both aldimine protons couple about equally to the N-methyl protons ($^5J \cong 0.8$ cps). This observation and the fact that only one of the N-methyl resonances of glucose methylphenylosazone tetraacetate is split by the aldimine protons ($^5J = 0.9$ cps) makes it clear that the aldimine protons couple

only to the N-methyl group of the terminal methylphenylhydrazone unit. Two structures have been considered for mixed osazone A (VIII and IX). Chemical evidence has been interpreted on the basis of structure



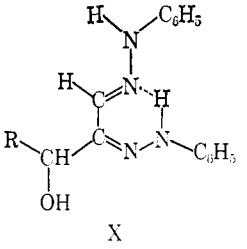
VIII



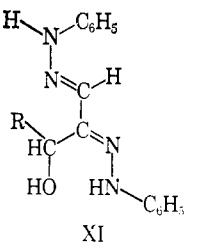
IX

IX.[12a] On the basis of the observations described above the aldimine proton in IX should split the N-methyl resonance while in VIII it should not. The aldimine proton in mixed osazone A tetra-O-acetate does split the N-methyl resonance. The assignment of structure IX to mixed osazone A is thus corroborated.

Formation of the alkazones is consistent with the Fieser hypothesis that chelate formation is the factor which halts phenylhydrazine oxidation, but it does not require that this hypothesis be true. In fact there is good reason to believe that chelate formation is not the factor which limits phenylhydrazine oxidation. There is no doubt that phenylosazones form chelates in solution.[12-14] On standing in solution, however, the chelate X equilibrates with a nonchelate isomer XI.[13] It is this process which is responsible for the mutarotation of phenylosazones.[13] The position of the equilibrium X $\rightleftarrows$ XI depends on the size of R.[13] The equilibrium in glyceraldehyde phenylosazone (X, R = H) is 50:50, X:XI.[13] It is thus clear that in solution sufficient nonchelate isomer will be present to react since the energy difference between the chelate and nonchelate isomers is small.[15] Phenylhydrazine oxidation of 1,-



X



XI

3-dihydroxyacetone does not go beyond the phenylosazone stage even on standing for weeks in homogeneous solution.[18] Chelation thus is probably not the limiting factor in the phenylhydrazine oxidation of sugars. The reason for the limited oxidation is an unanswered problem for which many possible answers may be considered. Investigation of this problem is now in progress.

Experimental Section

Preparation of Methylphenylpropazone. 1,3-Dihydroxyacetone (0.5 g), 1-methylphenylhydrazine (3.87 ml), and acetic acid (2.0 ml) were dissolved in 50% ethanol–water (10 ml). Within 1 min, an oil began to separate, and it soon solidified. The reaction mixture was allowed to set for 12 hr, at which time it was cooled, and the solid was collected and recrystallized from 95% ethanol (yield 2.07 g, 93%, mp 124.5–127°).

Anal. Calcd for $C_{24}H_{26}N_6$: C, 72.32; H, 6.57; N, 21.10. Found: C, 72.34; H, 6.42; N, 21.24.

Preparation of Methylphenylbutazone. Erythrose (0.50 g), 1-methylphenylhydrazine (3.87 ml), and acetic acid (2.00 ml) were dissolved in 50% ethanol–water (10 ml) and let stand at room temperature. Yellow crystals soon began to separate from the solution. After 1 day, the solution was cooled, and the crystals were collected and dried (yield 1.6 g, 72%). The crystals were recrystallized from absolute ethanol giving two crystalline modifications, mp 149–151° and 158–160°, which had superimposable nmr and infrared spectra in solution but different infrared spectra in potassium bromide pellets.

Anal. Calcd for $C_{32}H_{34}N_8$: C, 72.42; H, 6.46; N, 21.12. Found: C, 72.46; H, 6.43; N, 20.90.

Preparation of Methylphenylpentazone. Arabinose or xylose (0.50 g), 1-methylphenylhydrazine (3.87 ml), and acetic acid (2.00 ml) were dissolved in 50% ethanol–water (10 ml) and let stand at room temperature. After 2 days, the red gum which had deposited on the bottom of the flask was collected and crystallized from boiling absolute ethanol (yield arabinose 0.66 g, 30%; xylose 0.87 g, 39%), mp 150–152°.

Anal. Calcd for $C_{40}H_{42}N_{10}$: C, 72.48; H, 6.38; N, 21.13. Found: C, 72.48; H, 6.58; N, 21.25.

Preparation of Methylphenylhexazone. Fructose (0.5 g), 1-methyl-1-phenylhydrazine (4.2 ml), and acetic acid (5 ml) were dissolved in 66% ethanol–water (10 ml). After several days the precipitate in the flask was collected and recrystallized from pyridine. More precipitate was isolated from the reaction at later intervals (yield ~40 mg, 2%), mp 262–264°.

Anal. Calcd for $C_{48}H_{50}N_{12}$: C, 72.51; H, 6.34. Found: C, 72.51; H, 6.30.

The Preparation of the 1,3-Bismethylphenyl-2-phenylpropazone. Phenylhydrazine (0.10 g) was added to a saturated solution of methylphenylpropazone (III, 0.20 g) in absolute ethanol containing 1 drop of acetic acid. A yellow solid immediately separated. The solid was collected and recrystallized from absolute ethanol (yield 90%, mp 191–191.5°).

Anal. Calcd for $C_{28}H_{24}N_6$: C, 71.84; H, 6.29; N, 21.86. Found: C, 71.86; H, 6.04; N, 22.08.

Isolation of Glyoxal Methylphenylosazone from the Oxidation of Glucose Methylphenylosazone with 1-Methylphenylhydrazine. Glucose methylphenylosazone (0.50 g), 1-methylphenylhydrazine (1.58 g), acetic acid (2.0 ml), water (8.0 ml), and ethanol (10 ml) were mixed and let stand at room temperature. After 4 weeks, ether (100 ml) was added to the solution which was then extracted with 25% hydrochloric acid. The extracts were discarded. The ether solution was washed with saturated sodium bicarbonate and sodium chloride solution and dried over magnesium sulfate. The ether was removed with a rotary evaporator and the residue chromatographed on silica gel. A single compound (mp 216–220°) was eluted with chloroform and was shown to have nmr and infrared spectra identical with those of glyoxal methylphenyloxazone (mp 216–220°),[19] prepared by the method used by von Pechmann for the preparation of glyoxal phenylosazone.[20]

Preparation of Methylphenylmethazone. Formaldehyde (7.5 g of a 40% aqueous solution) and methylphenylhydrazine (12.2 g) were mixed. After 10 min, water was added, and the product was steam distilled. The oil in the distillate was extracted with ether; the ether extracts were dried, and the ether was removed. The methylphenylmethazone thus obtained was distilled, bp 114–115°

(12) (a) L. Mester, *J. Am. Chem. Soc.*, **77**, 4301 (1955); (b) L. Mester and A. Major, *ibid.*, 77, 4305 (1955); (c) L. Mester, E. Moczar, and J. Parello, *Tetrahedron Letters*, 3223 (1964); (d) L. Mester, E. Moczar, and J. Parello, *J. Am. Chem. Soc.*, **87**, 596 (1965); (e) L. Mester, *Angew. Chem. Intern. Ed. Engl.*, **4**, 574 (1965).

(13) O. L. Chapman, R. W. King, W. J. Welstead, Jr., and T. J. Murphy, *J. Am. Chem. Soc.*, **86**, 4968 (1964).

(14) M. L. Wolfrom, G. Fraenkel, D. R. Lineback, and F. Komitsky, Jr., *J. Org. Chem.*, **29**, 457 (1964); H. El Khadem, M. L. Wolfrom, and D. Horton, *ibid.*, 30, 838 (1965).

(15) It has been argued[12b,16] that the phenylosazones are nonclassical aromatic systems. This cannot be because of the small free-energy difference between X and XI.[13,17]

(16) L. C. Dorman, *Tetrahedron Letters*, 459 (1966).

(17) O. L. Chapman, *ibid.*, 2599 (1966).

(18) It is important that the chelate be kept in solution since crystallization of a less soluble chelate might be a limiting factor in the oxidation.

(19) H. v. Pechmann, *Ber.*, 30, 2871 (1897).

(20) H. v. Pechmann, *ibid.*, 30, 2459 (1897).

(15 mm); nmr, aromatic protons (δ 7.51, 5 H), aldimine protons (δ 6.54 and 6.59; 2 H, J_{AB} = 11.3 cps), and N-methyl protons (δ 3.01, 3 H).

Anal. Calcd for $C_8H_{10}N_2$: C, 71.60; H, 7.51; N, 20.93. Found: C, 71.60; H, 7.76; N, 20.73.

Acknowledgment. This research was supported by Grant CA 08540 from the National Cancer Institute, U. S. Public Health Service, Department of Health, Education and Welfare.

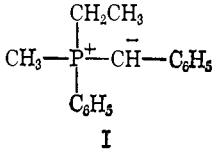
Scope and Mechanism of the Reaction of Alkylidenephosphoranes with Nitriles

Robert Gordon Barnhardt, Jr., and William E. McEwen

Contribution from the Department of Chemistry of the University of Massachusetts, Amherst, Massachusetts 01003. *Received August 15, 1967*

Abstract: The scope of the reaction of a phosphonium ylide with a nitrile, with subsequent acid-catalyzed hydrolysis of the adduct, has been explored. In reactions of both aliphatic and aromatic nitriles with ylides derived from ethyltriphenylphosphonium iodide, triphenylbenzylphosphonium iodide, tetra-*n*-butylphosphonium iodide, tri-*n*-butylbenzylphosphonium iodide, and methylethylphenylbenzylphosphonium iodide, very good yields of ketones were obtained. It was also found that the yield of the condensation product of nitrile and ylide was markedly dependent on the nature of the lithium salt (derived from the phosphonium halide and organolithium reagent in the generation of the ylide) present in the reaction mixture. Control experiments indicated that the effect was attributable to activation of the nitrile by Li^+. The lithium ion is functioning as an activating agent (Lewis acid) in the condensation step. The use of (+)-methylethylphenylbenzylphosphonium iodide in condensation reactions with benzonitrile, *p*-methylbenzonitrile, and *p*-chlorobenzonitrile also helped to clarify some of the details of the mechanism of the over-all reaction.

Some time ago, we reported[1] that the condensation of methylethylphenylbenzylidenephosphorane (I) with benzonitrile gave an adduct which, on base- or acid-catalyzed hydrolysis, afforded desoxybenzoin and methylethylphenylphosphine oxide in high yield. Some insight into the mechanism of the reaction was also gained by the use of optically active I in the same reaction sequence. We have now expanded the scope of this reaction by the use of a variety of phosphonium ylides and nitriles in the condensation reaction and we have looked further into the mechanism of the reaction by means of a study of the stereochemistry of the reaction of optically active I with some *para*-substituted benzonitriles and also by examination of certain metal cation effects.



I

The results of the reactions of various nitriles with ylides derived from a number of fundamentally different types of phosphonium salts are given in Table I. In all cases reported in Table I, the initial adduct was subjected to acid-catalyzed hydrolysis.

As shown in Table I, ylides derived from phosphonium iodides react with nitriles to give, generally, quite high yields of ketones. However, under identical conditions, ylides derived from the corresponding phosphonium chlorides and phosphonium bromides are able to bring about little, if any, conversion of nitriles to ketones. It appears to be of fundamental importance that the phosphonium iodides react with the organolithium compounds to give, at the equivalence point, homogeneous solutions, whereas the corresponding chlorides and bromides give, at the equivalence point, heterogeneous mixtures. It was found, moreover, that a typical unreactive ylide mixture (generated by the action of methyllithium on triphenylbenzylphosphonium chloride) could be caused to react with *p*-chlorobenzonitrile, for example, by the addition of powdered, anhydrous lithium iodide to the reaction mixture. A yield of 81% of 4′-chlorodesoxybenzoin was thus obtained.

That the apparent "anion effect" is actually due to the presence of *dissolved* lithium ions rather than to iodide ions was demonstrated experimentally as follows. Addition of an equivalent quantity of tetraphenylphosphonium iodide to an unreactive ylide mixture (generated in benzene medium from triphenylbenzylphosphonium chloride) led to no increase in the yield of condensation product. However, treatment of an identical unreactive ylide mixture with an equivalent quantity of anhydrous lithium perchlorate brought about conversion of *p*-chlorobenzonitrile to 4′-chlorodesoxybenzoin in 68% yield. The fact that treatment of the unreactive ylide mixture with 0.2 equiv of lithium perchlorate led to the isolation of 4′-chlorodesoxybenzoin in but 19% yield indicates that the soluble lithium salts do not function as true catalysts, but are better described as activating reagents.

That lithium iodide remains dissolved in ether, dioxane, or benzene in the presence of the ylides, whereas lithium chloride and lithium bromide precipitate under identical circumstances, can be explained by the assumption that the ylides, being dipolar molecules, are able to interact with lithium iodide strongly enough

(1) A. Blade-Font, W. E. McEwen, and C. A. VanderWerf, *J. Am. Chem. Soc.*, 82, 2646 (1960).