based on oxygen consumed). *Anal.* Calcd. for $C_{10}H_{14}O_2$: C, 72.26; H, 8.49; hydroperoxide equiv., 166. Found: C, 72.5; H, 8.3; hydroperoxide equiv., 167.8, 168.3.

**Symmetrical Dialkyl Peroxides.**—Symmetrical *t*-butyl, *t*-amyl and *t*-hexyl peroxides can be made relatively easily.[16] The higher homologs are more difficult to prepare since the acid concentrations and temperatures required to effect condensation lead to dehydration of the alcohol and rearrangement of the hydroperoxide components. Symmetrical 3-methyl-3-hexyl peroxide was made in low yield. The higher homolog, bis-3-ethyl-3-hexyl peroxide, could not be prepared under various conditions of acid strength and temperature.

**Bis-(3-methyl-3-hexyl) Peroxide.**—A 65% sulfuric acid solution (65 g. of sulfuric acid and 35 g. of water) was chilled to 0°. To the reaction were added 42 g. of 3-methyl-3-hexanol and 40 g. of 3-methyl-3-hexyl hydroperoxide and the reaction stirred overnight at 0° with rapid stirring. The hydroperoxide titer decreased to 58%. In addition to the recovered alcohol (40%) and hydroperoxide (45%) there was obtained 50% of dehydration products consisting of a mixture of heptenes (b.p. 86–95° (760 mm.), $n^{20}\text{D}$ 1.4051–1.4103; lit. 3-methyl-hexene-2, b.p. 93°, $n^{20}\text{D}$ 1.4075; 3-methyl-hexene-3, b.p. 94°, $n^{20}\text{D}$ 1.4050) and 3 g. of bis-(3-methyl-3-hexyl) peroxide. The repetition of this procedure several times yielded sufficient peroxide to distil (b.p. 42–43° (1 mm.), $n^{20}\text{D}$ 1.4302). *Anal.* Calcd. for $C_{14}H_{30}O_2$: C, 72.98; H, 13.13. Found: C, 73.0, 72.7; H, 13.0, 13.0. Calcd. for $C_7H_{14}$: C, 85.63; H, 14.37. Found: C, 85.7; H, 14.4.

***t*-Butyl *t*-Alkyl Peroxides.**—Although symmetrical dialkyl peroxides of the higher homologs could not be prepared by the sulfuric acid method, the unsymmetrical *t*-butyl peroxides could be made. The unbranched *t*-alkyl *t*-butyl peroxides were synthesized from the alcohol and *t*-butyl hydroperoxide. However, branching in one of the carbinol substituents often caused substantial amounts of rearranged products to be formed. Thus, methylethylisopropylcarbinol and *t*-butyl hydroperoxide yielded a mixture of *t*-butyl 2,3-dimethyl-3-pentyl peroxide and *t*-butyl 2,3-dimethyl-2-pentyl peroxide. Similarly, methylisopropylbutylcarbinol and methylpropyl-*sec*-butylcarbinol all gave *t*-butyl *t*-alkyl peroxide mixtures. The criterion for rearrangement in this series of *t*-butyl alkyl peroxides was the examination of the thermolysis products. Thus, "*t*-butyl 2,3-dimethyl-3-pentyl peroxide" on thermolysis yielded butene (30%) in addition to the expected ethane (50%) and propane (40%). The other branched alcohols also yielded peroxides which produced anomalous alkane fragments on thermolysis.

**3-Methyl-3-hexyl *t*-Butyl Peroxide.**—A sulfuric acid solution (65%, 65 g. of sulfuric acid and 35 g. of water) was chilled to 0° and 40 g. of 3-methylhexanol-3 and 30 g. of *t*-butyl hydroperoxide were added. The reaction was stirred for 4 hours at 0° and 18 hours at 13°. Ether was added and the ethereal solution washed with water, dried with sodium carbonate and distilled. The peroxide 3-methyl-3-hexyl *t*-butyl peroxide is obtained in 93% (60 g.) yield (b.p. 39–40° (1 mm.), $n^{20}\text{D}$ 1.4124). *Anal.* Calcd. for $C_{11}H_{24}O_2$: C, 70.16; H, 12.85. Found: C, 70.4, 70.3; H, 12.9, 12.8.

**3-Ethyl-3-hexyl *t*-Butyl Peroxide.**—A 65% sulfuric acid solution (65 g. of sulfuric acid and 35 g. of water) was chilled to 0°. With rapid stirring and chilling 40 g. of 3-ethyl-3-hexanol was added and followed by 30 g. of *t*-butyl hydroperoxide. The reaction was stirred at 0° for 15 hours. Ether (100 ml.) was added and the organic layer separated. It was washed with water, dried with sodium carbonate and distilled. The 3-ethyl-3-hexyl *t*-butyl peroxide was obtained as a liquid boiling at 52–53° (1 mm.) in 88% (53 g.) yield ($n^{20}\text{D}$ 1.4195). *Anal.* Calcd. for $C_{12}H_{26}O_2$: C, 71.23; H, 12.95. Found: C, 71.8, 71.7; H, 13.0, 13.0.

**4-Methyl-4-octyl *t*-butyl peroxide** was obtained from 24 g. of 4-methyl-4-octanol, 32 g. of *t*-butyl hydroperoxide (TBHP) and 100 g. of 65% $H_2SO_4$ at 0° which was stirred at 5–6° for 20 hours; yield 26 g., boiling range 53–54° (1 mm.), $n^{25}\text{D}$ 1.4179. *Anal.* Calcd. for $C_{13}H_{28}O_2$: C, 72.16; H, 13.05; mol. wt., 216. Found: C, 71.7, 71.8, H, 13.0, 13.1; mol. wt., 220.

**4-Ethyl-4-octyl *t*-butyl peroxide** was prepared from 4-ethyl-4-octanol (21 g.), TBHP (32 g.) and 100 g. of 65% sulfuric acid at 0°. The mixture was stirred 16 hours at 0° and 7 hours at 4–8° to yield 21 g., boiling range 53–54°(1 mm.), $n^{25}\text{D}$ 1.4232. *Anal.* Calcd. for $C_{14}H_{30}O_2$: C, 72.98; H, 13.13; mol. wt., 230 Found: C, 73.0, 72.9; H, 13.0, 13.1; mol. wt., 225.

**Analysis of Gases.**—The gas samples were collected from the reaction mixtures by distillation into a liquid nitrogen trap. The molecular distillation was repeated and the gas sample analyzed mass spectroscopically. Mixtures were also examined by gas liquid chromatograph on a 50-ft. dimethyl sulfolane–firebrick column at 0°: air, 5.1′; ethane, 6.2′; propane, 9.2′; and butane, 19.2′. Methane was separated from air on an 8 ft. silica gel column at 0°: air, 1.0′; methane, 2.0′; ethane, 12.5′.

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[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF MICHIGAN, ANN ARBOR, MICH.]

# Some Factors Affecting the Site of Alkylation of Oxime Salts

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The product ratio for alkylation of oxime salts on oxygen to that on nitrogen has been studied by chromatographic separation. In the methylation and benzylation of *p,p′*-disubstituted benzophenone oxime sodium salts in ethanol, electron-withdrawing groups markedly promote alkylation on oxygen. In the alkylation of benzophenone oxime sodium salt with *p*-substituted benzyl halides, electron-withdrawing substituents also favor alkylation on oxygen, but only weakly. No systematic difference in product ratio was detected among oxime salts of lithium, sodium, potassium and tetramethylammonium. O-Alkylation is increased mildly in 1:1 acetone–ethanol solution, but is not affected by small amounts of water in ethanol. Heterogeneous experiments in acetone show overwhelming O-alkylation, but in toluene O-alkylation is slightly depressed. Variation of leaving groups among benzyl chloride, bromide and tosylate showed a questionably small effect on the O/N ratio. Treatment of benzophenone oxime with neat benzyl bromide heavily favored N-alkylation, but resulted in a much slower reaction.

Interest in the alkylation of ambident anions from both the standpoints of mechanism and synthesis has increased considerably in recent years. Several unanticipated effects of structural changes and of experimental conditions have been reported, and different theories have been advanced in their explanation.[2–4] Most of the systematic work has been done with only a small variety of systems, principally nitrite and phenol salts; only the latter are susceptible to the study of substituent effects on the anion, but this has not yet been reported.

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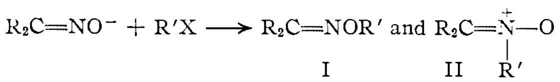
(1) From the doctoral dissertation of J. E. R., 1959; Procter and Gamble Fellow and Harris Scholar.

(2) (a) N. Kornblum, R. A. Smiley, R. K. Blackwood and D. C. Iffland, *J. Am. Chem. Soc.*, **77**, 6269 (1955); (b) N. Kornblum and A. O. Lurie, *ibid.*, **81**, 2705 (1959); (c) N. Kornblum and R. Seltzer, *ibid.*, **83**, 3668 (1961), and references therein.

(3) R. Barner and H. Schmid, *Helv. Chim. Acta*, **43**, 1393 (1960).

(4) (a) D. Y. Curtin, R. J. Crawford and M. Wilhelm, *J. Am. Chem. Soc.*, **80**, 1391 (1958); (b) D. Y. Curtin, R. C. Tuites and D. H. Dybvig, *J. Org. Chem.*, **25**, 155 (1960), and references therein.

Oxime anions, whose alkylation has been of occasional synthetic interest to us, are available in enormous structural variety at small cost in effort. Alkylation has long been known to occur both on oxygen to give oxime ethers (I), and on nitrogen to give nitrones (II). Goldschmidt has shown that methylation of aldoxime salts is a second-order process, whose rate depends on oxime anion and alkyl halide concentrations. Brady and co-workers[5-8] have reported the only systematic investigation of the subject, at a time when concepts of reaction mechanism were in their infancy; their work was confined largely to aldoximes. We have now re-examined their conclusions and extended the investigation to *p*-substituted benzophenones.



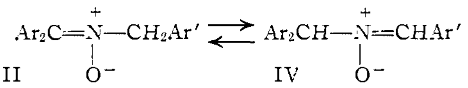
$$R_2C{=}NO^- + R'X \longrightarrow \underset{\text{I}}{R_2C{=}NOR'} \text{ and } \underset{\text{II}}{R_2C{=}\underset{R'}{\overset{+}{N}}{-}O}$$

## Results

Except where specifically noted, all alkylation reactions were carried out under the same set of conditions. The oxime was dissolved in an absolute ethanol solution containing an equivalent amount of sodium ethoxide and of such a volume as to make a 0.50 *M* solution. An equivalent amount of alkylating agent was added, and the reaction allowed to proceed at room temperature for such lengths of time, usually 24 to 48 hours, that alkylation was nearly complete, as indicated by pilot experiments or by precipitation of products. The mixtures were in nearly all such cases initially clear, homogeneous solutions, and usually remained so. However, when chlorides were used as alkylating agents, sodium chloride precipitated during the reaction, and in some cases a portion of the organic products crystallized.

The products were determined by evaporating the solvent, triturating the residue with a nonpolar solvent (usually carbon tetrachloride) and filtering to remove inorganic salts, followed by chromatography on Florisil to separate the organic products, which were isolated and weighed. The accuracy of the method was checked by applying it to a synthetic mixture of the benzylation products of benzophenone oxime in which the amounts corresponded to an O-:N-alkylation ratio of 2.66; total recovery was 98% in an O-:N-alkylation ratio of 2.76. Owing to the laboriousness of the chromatographic product analyses, we were not able to do every experiment in duplicate. However, in five representative cases, duplicate experiments showed close agreement in product ratios, the differences being 0, 3, 4.5, 8 and 8% (see the accompanying tables). The accuracy is not uniform, for the sharpness of the separations, as shown by the melting points of the chromatographic fractions, varied with structure, but we estimate the errors in the ratios to be less than 10% in most if not all cases. Analysis was also attempted by chromatography on alumina, solvent extraction, selective hydrolysis, polarography, and ultraviolet and infrared spectrometry, but none was completely satisfactory. Initial experiments with fluorenone oxime were abandoned in favor of benzophenone oxime when it was found that alkylation of the former was too one-sided in favor of O-alkylation.

In addition to the primary products of alkylation, there were usually isolated unreacted oxime (0 to 40%, mostly 3 to 10%), ketone (0 to 19%, mostly <5%), and an isomeric nitrone. The last two were shown to be secondary products arising from the primary nitrones, which hydrolyze relatively easily to give ketone,[8] and in some cases undergo base-catalyzed tautomerization[9,10] leading in the present examples to N-benzhydrylbenzaldoximes. The actual extent of N-alkylation is thus the sum of the amounts of both the nitrones and ketone; the ratios given in the tables are calculated from the sums. The apparent material balances were mostly 96 to 102%; the occasional recoveries of over 100% of products is believed to be due to traces of adsorbent carried through.



$$\underset{\text{III}}{Ar_2C{=}\underset{O^-}{\overset{+}{N}}{-}CH_2Ar'} \rightleftarrows \underset{\text{IV}}{Ar_2CH{-}\underset{O^-}{\overset{+}{N}}{=}CHAr'}$$

Tautomerization of nitrones, discovered by Behrend,[9] was observed only with benzyl and not with methyl substitution. The extent of it appeared to depend on reaction time and on structure, and probably also on the small unavoidable amounts of excess alkoxide that were probably present in some experiments. The unsubstituted system (derived from benzylation of benzophenone oxime) appeared to come to equilibrium at a ratio of 0.5 for III/IV, although no attempt was made to establish that this was indeed an equilibrium value. The various ratios are tabulated in the Experimental section. We did not detect any of the aldehydes that might have been formed from hydrolysis of the tautomerized nitrones during the alkylation experiments. However, the identity of the various nitrones obtained was established in each case by hydrolysis of one or both isomers and identification of the aldehyde or ketone formed.

The influence of reaction medium on the reaction of benzyl bromide with sodium benzophenone oximate was briefly looked at, in the first instance to find out if there might be a significant difference between reactions carried out in commercial absolute alcohol (*ca.* 99.5%) and in strictly anhydrous alcohol. (Goldschmidt[11] has reported that there is no significant effect on the rate of methylation of oxime salts in ethanol caused by small amounts of water.) When no difference was found, most of the reactions were carried out in the commercial solvent. The results of varying the medium, including added salt and dilution, are summarized in Table I. In addition, benzylation of free benzophenone oxime with benzyl bromide without a solvent for a period of 78 days resulted in 13% O-benzylation, 36% N-benzylation (ratio O-:N-, 0.34) and 37% recovered oxime. Attempts to benzylate free

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(5) O. L. Brady, F. P. Dunn and R. F. Goldstein, *J. Chem. Soc.*, 2386 (1926).

(6) O. L. Brady and R. F. Goldstein, *ibid.*, 2403 (1926).

(7) O. L. Brady and L. Klein, *ibid.*, 874 (1927).

(8) O. L. Brady and N. M. Chokshi, *ibid.*, 2271 (1929).

(9) R. Behrend, *Ann.*, **265**, 238 (1891).

(10) C. Neubauer, *ibid.*, **298**, 187 (1897).

(11) H. Goldschmidt, *Z. Elektrochem.*, **14**, 581 (1908).

TABLE I

MEDIUM EFFECTS ON THE BENZYLATION OF BENZOPHENONE OXIME SODIUM SALT

| Medium | Duration, hours | Recovered oxime, % | O-Alkyl oxime, % | Benzophenone, % | Nitrones | | % O-Alkylation / % N-Alkylation |
|---|---|---|---|---|---|---|---|
| | | | | | Aldo, % | Keto, % | |
| Abs. EtOH (99.5%) | 48 | 6 | 70 | 2 | 6 | 17 | 2.8 |
| Anhyd. EtOH (99.99%)[a] | 144 | 4 | 71 | 0 | 17 | 7 | 3.0 |
| 50% EtOH–50% acetone | 24 | 1 | 80 | 0 | 10 | 7 | 4.7 |
| 0.68 $M$ NaI in EtOH | 24 | 3 | 76 | 0 | 13 | 12 | 2.9 |
| Acetone[b] | 168 | 0 | 94 | 0 | 0 | 2 | 57.0 |
| Toluene[b] | 168 | 29 | 46 | 0 | 0 | 22 | 2.1 |
| Abs. EtOH, 20-fold diln.[c] | 576 | 31 | 53 | 0 | 11 | 6 | 3.1 |

[a] Dried by distillation from magnesium ethoxide. [b] Heterogeneous. [c] *I.e.*, reactants 0.025 $M$ instead of the usual 0.5 $M$.

TABLE II

COMPARISON OF LEAVING GROUPS IN THE BENZYLATION OF BENZOPHENONE OXIME SODIUM SALT IN ABSOLUTE ETHANOL

| Leaving group | Duration, hours | Recovered oxime, % | O-Alkyl oxime, % | Benzophenone, % | Nitrones | | % O-Alkylation / % N-Alkylation |
|---|---|---|---|---|---|---|---|
| | | | | | Aldo, % | Keto, % | |
| Br | 48 | 6 | 70 | 2 | 6 | 17 | 2.8 |
| Cl | 56 | 13 | 66 | 0 | 14 | 6 | 3.3 |
| $p$-$C_7H_7SO_3$ | 56 | 19 | 60 | 0 | 11 | 6 | 3.5 |

TABLE III

COMPARISON OF CATIONS IN THE BENZYLATION OF BENZOPHENONE OXIME SALTS IN ABSOLUTE ETHANOL

| Cation | Duration, hours | Recovered oxime, % | O-Alkyl oxime, % | Benzophenone, % | Nitrones | | % O-Alkylation / % N-Alkylation |
|---|---|---|---|---|---|---|---|
| | | | | | Aldo, % | keto, % | |
| $Li^+$ | 144 | 6 | 73 | 1 | 11 | 11 | 3.2 |
| $Na^+$ | 48 | 6 | 70 | 2 | 6 | 17 | 2.8 |
| $K^+$ | 16 | 19 | 61 | 2 | 0 | 14 | 3.8 |
| $K^+$ | 64 | 8 | 77 | 2 | 0 | 20 | 3.5 |
| $(CH_3)_4N^+$ | 24 | 8 | 69 | 0 | 2 | 21 | 3.0 |

TABLE IV

ALKYLATION OF $(C_6H_5)_2CNONa$ WITH $p$-$RC_6H_4CH_2Br$ IN ABSOLUTE ETHANOL

| R | Duration, hours | Recovered oxime, % | O-Alkyl oxime, % | Benzophenone, % | Nitrones | | % O-Alkylation / % N-Alkylation |
|---|---|---|---|---|---|---|---|
| | | | | | Aldo, % | Keto, % | |
| $CH_3O$ | 84 | 18 | 57 | 0 | 0 | 28 | 2.0 |
| $CH_3$ | 48 | 10 | 70 | 3 | 18[a] | | 3.3 |
| $CH_3$ | 144 | 10 | 70 | 0 | 15 | 7 | 3.2 |
| H | 48 | 6 | 70 | 2 | 6 | 17 | 2.8 |
| H | 43 | 4 | 74 | 4 | 22[a] | | 2.8 |
| Cl[b] | 72 | 5 | 72 | 0 | 21 | 0 | 3.4 |
| CN | 40 | 9 | 72 | 0 | 8 | 11 | 3.8 |
| $NO_2$ | 72 | 0 | 76 | 0 | 0 | 0 | (>3) |

[a] Combined nitrones. [b] $p$-Chlorobenzyl chloride.

benzophenone oxime in 0.5 $M$ solution in ethanol were unsuccessful.

The effect of the leaving group was studied by comparing the alkylation of benzophenone oxime with benzyl chloride, bromide and $p$-toluenesulfonate. The results, shown in Table II, show differences that appear to be only just greater than the estimated uncertainty of the values of the ratios.

Variation in the cationic moiety of the benzophenone salt was studied by its effect on the site of reaction with benzyl bromide. The results, given in Table III, do not show significant differences except in the case of the potassium salt. The rates of reaction, which were not investigated quantitatively, were observed to be qualitatively very different. Alkylation of the lithium salt was found to be less than 57% complete in 64 hours, while that of the potassium and sodium salts appeared to be over 90% complete in under 24 hours.

The results for the alkylation of unsubstituted benzophenone oxime with different benzyl bromides are summarized in Table IV. The low material balance, 76%, obtained with $p$-nitrobenzyl bromide, together with the total absence of recovered ketone or nitrone, suggest that the products of N-alkylation were destroyed by an unrecognized secondary reaction.

The alkylation of symmetrically substituted benzophenone oximes was carried out with both benzyl bromide and methyl bromide. Methyl bromide gave more N-alkylation in every case. The results are presented in Tables V and VI.

The nitrones and O-alkyl oximes isolated from the various experiments were mostly new compounds. Each of the nitrones showed a usually strong infrared absorption peak not present in the isomeric O-alkyl oxime between 1170 and 1280 cm.$^{-1}$, in which region the semi-polar N→O stretching frequency in amine oxides[12] and nitroso dimers[13] has been assigned, and may have a similar assignment. Absorption attributable to C–N

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[12] G. Costa and P. Blasina, *Z. physik. Chem.*, **4**, 24 (1955).

[13] B. G. Gowenlock, H. Spedding, J. Trotman and D. H. Whiffen, *J. Chem. Soc.*, 3927 (1957).

TABLE V

ALKYLATION OF $(RC_6H_4)_2CNONa$ WITH BENZYL BROMIDE IN ABSOLUTE ETHANOL

| R | Duration, hours | Recovered oxime, % | O-Alkyl oxime, % | Ketone, % | Nitrones | | % O-Alkylation / % N-Alkylation |
|---|---|---|---|---|---|---|---|
| | | | | | Aldo, % | Keto, % | |
| *p*-$CH_3O$ | 48 | 11 | 67 | 6 | 0 | 20 | 2.6 |
| *p*-$CH_3O$ | 72 | 10 | 62 | 16 | 0 | 10 | 2.4 |
| H | 48 | 6 | 70 | 2 | 6 | 17 | 2.8 |
| *p*-Cl | 36 | 6 | 76 | 3 | 0 | 14 | 4.5 |
| *m*-$NO_2$ | 56 | 4 | 88 | 0 | 7 | 4 | 8.9 |
| *p*-$NO_2$ | 15 | 13 | 84 | 0 | 0 | 4 | 21 |

TABLE VI

ALKYLATION OF $(RC_6H_4)_2CNONa$ WITH METHYL BROMIDE IN ABSOLUTE ETHANOL

| R | Duration, hours | Recovered oxime, % | O-Alkyl oxime, % | Ketone, % | Nitrone, % | % O-Alkylation / % N-Alkylation |
|---|---|---|---|---|---|---|
| *p*-$CH_3O$ | 24 | 9 | 37 | 19 | 38 | 0.65 |
| *p*-$CH_3O$ | 72 | 10 | 36 | 6 | 47 | 0.68 |
| H | 24 | 3 | 46 | 4 | 43 | 1.0 |
| *p*-Cl | 24 | 5 | 56 | 4 | 37 | 1.4 |
| *m*-$NO_2$ | 80 | 18 | 72 | 0 | 11 | 6.3 |

stretching[14] was always recognizable between 1030 and 1200 cm.$^{-1}$. The O-alkyl oximes each showed absorption not present in the isomeric nitrones 920 and 1005 cm.$^{-1}$, attributable to N–O stretching,[14] and between 1010 and 1060 cm.$^{-1}$, attributable to C–O stretching.[14] The C=N stretching absorptions were in all cases close to 1600 cm.$^{-1}$; in isomeric pairs, the frequency for the nitrone was usually slightly lower than that of the O-alkyl oximes, and never higher.

## Discussion

The influence of the nature of the solvent on the site of alkylation of ambident anions is inadequately understood to justify speculation about the few observations we have made in this field (Table I). However, the experiment in acetone, in which the oxime salt is insoluble, gives such a spectacularly different product ratio as to suggest that a heterogeneous reaction occurs, as demonstrated by Kornblum and Lurie[3] with *p*-*t*-octylphenoxide, in the present case strongly favoring O-alkylation. On the other hand, the great difference in the effect of insolubility between acetone and toluene suggests that, if this interpretation is correct, the mere presence of solid salt does not ensure that a kinetically significant heterogeneous reaction must occur. The similarity of the O-:N-alkylation ratio in toluene to those in homogeneous solutions may thus be due to a faster reaction with the low but continuously replenished concentration of salt in solution. A case of complete inertness of an aldoxime sodium salt suspended in ether to alkylation by benzyl chloride has been reported by Nerdel and Huldschinsky.[15] This subject obviously requires investigation in its own right.

We were interested in the suggestion of Brady and Goldstein[6] that the site of oxime alkylation depends on the degree of dissociation of the salt, a view that has also been used in more sophisticated form by Curtin and co-workers[4] in interpreting certain phenoxide alkylations. We were not able to verify such an effect, inasmuch as neither 20-fold dilution nor the presence of 0.68 *M* sodium iodide produced a significant change in product ratio.[16] The insignificant difference in product ratio among salts of cations of such different field strength as $Li^+$, $Na^+$ and $(CH_3)_4N^+$ (Table II) is also difficult to reconcile with the view that degree of dissociation is of major significance in determining the site of alkylation of oxime salts. We have no explanation for the small but apparently real influence in the potassium salt in increasing O-alkylation.

Brady and Goldstein's evidence[6] for an effect of degree of dissociation on the relative amounts of O- and N-alkylation was in the form of three types of experiments. Alkylation of the sodium salts of oximes in 0.5 *N* aqueous solution gave slightly less N-alkylation than in 2 *N* solution; alkylation in 2 *N* aqueous solution containing in addition 2 *N* sodium hydroxide gave less N-alkylation; and alkylation in 2 *N* aqueous solution containing in addition 4 *N* sodium chloride increased the amount of N-alkylation. We believe these results to be artifacts of the analytical method. Brady and Goldstein did not isolate any of the reaction products, but determined unreacted oxime by extracting the aqueous reaction mixtures with "several portions of chloroform," to remove alkylation products, and then precipitating the oxime by neutralization of the aqueous solution. This procedure would have extracted appreciable amounts of oxime with the chloroform, since oxime salts are significantly hydrolyzed in water ($K_a$'s for most oximes[8] are of the order of $10^{-11}$). In other work, done here by Dr. B. B. Lubitz, the extraction of free oximes from aqueous solutions of their salts has been demonstrated. The amount of oxime extracted would obviously be less in the presence of 2 *N* sodium hydroxide, which would repress hydrolysis, and more in 4 *N* sodium chloride, which would exert a salting-out effect; extraction of oxime from the more dilute solution by a fixed volume of chloroform would also be less efficient. These artifacts directly affect the ratios of supposed alkylation products, for Brady and Goldstein determined the extent of N-alkylation by acid hydrolysis of the extracted products and titration of N-alkylhydroxylamine with iodine; any oxime present would have counted in with this, since the hydroxylamine formed from it would also be oxidized by iodine.

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(14) F. A. Miller in H. Gilman, "Organic Chemistry, An Advanced Treatise," Vol. III, John Wiley and Sons, Inc., New York, N. Y., 1953; L. J. Bellamy, "The Infrared Spectra of Complex Molecules," John Wiley and Sons, Inc., New York, N. Y., 1958.

(15) F. Nerdel and I. Huldschinsky, *Chem. Ber.*, **86**, 1005 (1953).

(16) We are aware that in this experiment halide exchange presumably generated enough benzyl iodide for it to have accomplished a significant fraction of the oxime alkylation. In view of the low sensitivity and the trend of the O-:N-alkylation ratios to changes in the leaving group, this occurrence should not alter the significance of the experiment.

The direction of the errors is exactly that of the perturbations in the ratios reported. The amounts of O-alkylation were determined by difference.

Whether the results given in Table III reflect a real effect of the leaving group on the site of alkylation is perhaps questionable, in view of the closeness of the differences to the estimated uncertainty of the ratios. The ratios are in neither the same order as the anionic leaving ability[17] in either SN1 or SN2 processes nor the inverse order. The ratios are thus not in the order conforming to the generalization suggested by Kornblum, Smiley, Blackwood and Iffland[2] that greater carbonium ion character of the transition state favors alkylation at the more electronegative atom (*i.e.*, higher O-:N-alkylation ratios); and an effect of this sort, if operating here, would have to be small. A similar insensitivity of the alkylation-site ratios to leaving group has also been observed by Kornblum, Pink and Yorka[18] for the benzylation of the lithium salt of 2-nitropropane.

The effect of structural changes in the alkylating agent is shown by the data in Table IV, together with the result of methylation in Table VI. It is clear that electronic influences have only a very small effect. In view of this, the much higher proportion of N-alkylation shown by methyl bromide compared to any of the benzyl bromides suggests that steric hindrance is significant with the latter in favoring alkylation at the less hindered oxygen atom. The low O—:N-alkylation ratio for *p*-methoxybenzyl bromide may reflect a significant contribution from an SN1 process, which, as previously mentioned, might be expected to give a more nearly statistical ratio of products. At the other end of the electronic scale, it is not certain whether the ratio from *p*-nitrobenzyl bromide is really very high, or whether the incursion of other reactions, responsible for the low material balance, has made the result not comparable. This experiment was unique in that a striking succession of colors—purple, dark brown, light brown and finally orange—was displayed during the first few minutes of reaction. Similar colors have been reported[19] in the conversion of *p*-nitrobenzyl chloride to dinitrostilbene by treatment with alcoholic alkali, and such a reaction may have occurred to some extent in our alkylation experiments.

Nevertheless, it is still possible to derive a qualitative correlation of the observed ratios with the relative rates of alkylation of amines and anions by substituted benzyl halides, by making use of the interpretation of Swain and Langsdorf.[20] Since one cannot write an arrangement of the electrons in oxime anions that puts a formal negative charge on nitrogen, SN2 attack on an alkylating agent by the unshared electron pair on the nitrogen may be considered similar to attack by an amine; in both cases a formal positive charge is generated on the nitrogen. Electron-donating groups on benzyl halides accelerate reactions of this sort, presumably by dissipating the developing charge, and electron-withdrawing groups decelerate them. Considering this aspect alone, one would expect *p*-methoxybenzyl halides to give a low O-:N-alkylation ratio in reaction with oxime anions, and *p*-nitrobenzyl halides to give high ratios. On the other hand, alkylation on oxygen, on which the negative charge of oxime anions formally resides, corresponds to the general case of SN2 attack by anions, which with benzyl halides is accelerated by all *p*-substituents, in the order $CH_3 < Cl < CH_3O < CN < NO_2$. Thus with *p*-nitrobenzyl halides both situations act to heighten the O—:N-alkylation ratio, while with *p*-methoxybenzyl halides there is opposition between a weak acceleration of O-alkylation and a strong acceleration of N-alkylation. Similar but less pronounced effects obtain for the other substituents. Whether or not this is a satisfactory interpretation of benzylation of oxime salts, the results in Table IV do not suggest the operation of the principle that substitution at the more electronegative atom is favored by increasing carbonium ion character in the transition state. The trend is actually opposite to that observed by Kornblum, Blackwood, Smiley and Iffland for the reaction of silver nitrite with benzyl halides in ether.

Tables V and VI show that the susceptibility of the alkylation ratios to substituents on the benzophenone moiety is much greater than to those on the benzylating agent (Table IV). The ratio of O- to N-alkylation is presumably kinetically determined (interconversion of benzyl oximes does not occur), and Brady and Goldstein[6] have shown that the O—:N-alkylation ratio is independent of the stage of completion, from which one can conclude that alkylation at each site follows a rate equation of the same order. Therefore, the rate of N-alkylation must be more susceptible to substituents than is the rate of O-alkylation, in order to account for the direction of the effects. Since the product ratios are determined by differences in rate, they can be expected to be correlatable by a combined Hammett equation

$$\log \frac{\%\ \text{O-alkylation}}{\%\ \text{N-alkylation}} = \sigma\rho' + \log k^0_{\text{O}}/k^0_{\text{N}}$$

where $\rho'$ is $\rho_O$-$\rho_N$, and the subscripts refer to the site of reaction. A plot of the logarithm of product ratios for benzylation against $\sigma$ is linear, as shown in Fig. 1, if for the *p*-nitro case the $\sigma^-$ value is used. The plot for the methylation ratios is also probably linear, although the fit is less satisfactory (and the number of points fewer). This situation corresponds to an inductive effect that acts most strongly on the nitrogen, which is nearer, modified as structures permit by mesomeric delocalization of the negative charge of the oxime anion and the nitrone.

Brady and Chokshi[8] earlier considered the effect of structural changes in aldoximes on the site of alkylation, and showed that the limited data could be correlated with the acidic dissociation constants. Since these also depend in the same way on influences on electron density in the oximino group, our results are in harmony with the earlier ones.

Oxime anions have been treated in this discussion as strictly dually ambident, although they can be formally considered as triply ambident. They are

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[17] A. Streitwieser, Jr., *Chem. Revs.*, **56**, 602, 654 (1956).

[18] N. Kornblum, P. Pink and K. V. Yorka, *J. Am. Chem. Soc.*, **83**, 2779 (1961).

[19] P. Walden and A. Kernbaum, *Ber.*, **23**, 1959 (1890).

[20] C. G. Swain and W. P. Langsdorf, Jr., *J. Am. Chem. Soc.*, **73**, 2813 (1951).

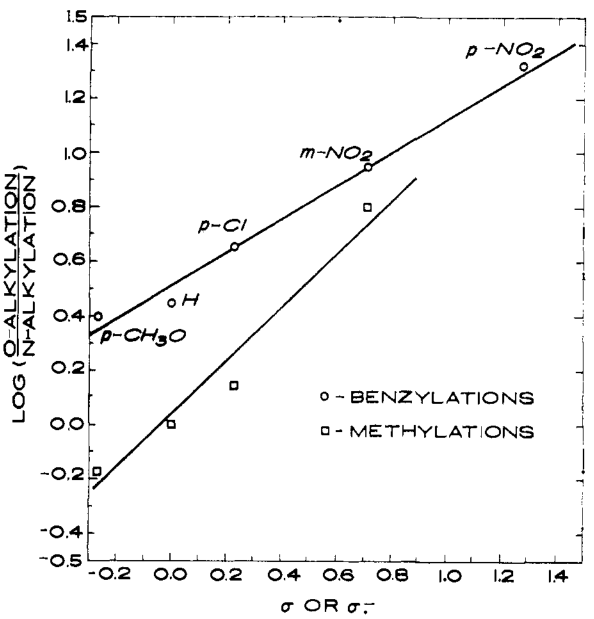


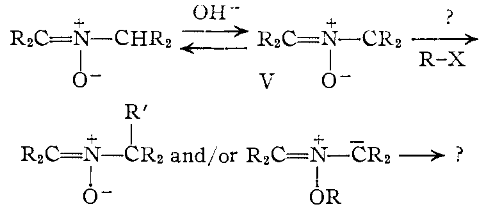
Fig. 1.—Hammett plot of product ratios from alkylation of benzophenone oximes.

isoelectronic with nitrite ion, to which they are related by the replacement of an oxygen by a methylene, and, as Nerdel and Huldschinsky[15] have pointed out, can be written as the carbanions of nitroso hydrocarbons. We were interested in the possibility that in

$$R_2C{=}N{-}O^- \longleftrightarrow R_2\bar{C}{-}N{=}O$$

favorable cases some alkylation might take place on carbon, analogously to the alkylation of nitroalkane anions,[18,21] leading to nitroso compounds. We were unable to find any evidence of such a reaction, and observed no transient colors that might have been due to small amounts of such compounds (the colors observed with $p$-nitrobenzyl bromide were never the blue or green to be expected of the nitroso compound). Steric hindrance would, of course, operate selectively against carbon alkylation.

Behrend's tautomeric interconversion of aldonitrones (III ⇄ IV) was originally suggested[9,10] to occur by alternate addition and elimination steps. It was shown to be reversible in certain cases, but to be far from general. The present work shows that it occurs with ketonitrones as well. It seems most probable that it is a case of simple reversible proton removal under the influence of base. If such is the case, the intermediate ion V would be of some interest, being isoelectronic with nitrate ion and nitroalkane anions. It might be expected to alkylate if formed in the presence of a suitable reagent to produce a more highly branched nitrone by alkylation on carbon, or an alkoxynitrene, which might cleave to aldehyde and ketimine or cyclize to an N-alkoxyaziridine, by alkylation on oxygen. No products attributable to such reactions were detected in our oxime alkylation experiments, but the amounts of them formed would be expected to be very small under such unfavorable conditions.



$$R_2C{=}\underset{O^-}{\overset{+}{N}}{-}CHR_2 \overset{OH^-}{\rightleftarrows} R_2C{=}\underset{O^-}{\overset{+}{N}}{-}CR_2 \xrightarrow[R\text{-}X]{?} \quad \text{V}$$

$$R_2C{=}\underset{O^-}{\overset{+}{N}}{-}\overset{R'}{C}R_2 \text{ and/or } R_2C{=}\underset{OR}{\overset{+}{N}}{-}\bar{C}R_2 \longrightarrow ?$$

## Experimental[22]

**Ketones and Oximes.**—Benzophenone, $p,p'$-dichloro-, $p,p'$-dimethoxy- and $p,p'$-dimethylbenzophenones were obtained from Eastman Organic Chemicals Co. $p,p'$-Dinitrobenzophenone was prepared by the chromic acid oxidation of p,p'-dinitrodiphenylmethane.[23] $m,m'$-Dinitrobenzophenone was prepared by nitration of benzophenone by the procedure of Barnett and Mathews.[24] Oximes were prepared by treatment with hydroxylamine hydrochloride in boiling pyridine, and were recrystallized from methanol or ethanol before use. Their melting points agreed with previously reported values, except in the case of $m,m'$-dinitrobenzophenone oxime, for which we observed m.p. 175–176° after repeated recrystallizations (reported[25] m.p. 205–207°). The compound had infrared absorption at 3200 (O—H) and 1620 cm.$^{-1}$ (C=N), and had the correct elemental analysis.

*Anal.* Calcd. for $C_{13}H_9N_3O_5$: C, 54.36; H, 3.16. Found: C, 54.41; H, 3.24.

**Oxime Salts.**—The sodium salt of benzophenone oxime was prepared by reaction of benzophenone oxime in ether with metallic sodium, according to the directions of Exner.[26] Its identity was confirmed by quantitative conversion back to benzophenone oxime, m.p. 137–138° (reported[27] m.p. 141–142°), by acidification.

The lithium and potassium salts of benzophenone oxime were prepared *in situ* without isolation, by adding an equiv-

TABLE VII

CHROMATOGRAPHIC SEPARATION OF PRODUCTS FROM BENZYL BROMIDE AND THE SODIUM SALT OF BENZOPHENONE OXIME 0.025 $M$ IN ETHANOL

| Eluent | | Residue | | |
|---|---|---|---|---|
| Vol., ml. | Composition, CCl$_4$: CHCl$_3$ | Wt., mg. | M.p., °C. | Identity[a] |
| 20 | 1:0 | .. | ... | |
| 20 | 1:0 | 34.8 | 60–61 | OA |
| 20 | 1:0 | 300.6 | 61–62 | OA |
| 20 | 1:0 | 40.9 | 61–62 | OA |
| 30 | 9:1 | 7.8 | 57–58 | OA |
| 30 | 9:1 | .. | ... | |
| 30 | 8:2 | 10.2 | 142–143 | Ox |
| 30 | 8:2 | 31.8 | 142–143 | Ox |
| 30 | 8:2 | 47.2 | 143–144 | Ox |
| 30 | 7:3 | 62.5 | 121–132[b] | Ox |
| 30 | 7:3 | 38.9 | 154–157 | AN |
| 30 | 7:3 | 12.7 | 158–161 | AN |
| 30 | 6:4 | 9.7 | 108–109 | AN + KN |
| 30 | 6:4 | 18.4 | 119–121 | KN |
| 30 | 1:1 | 17.7 | 119–121 | KN |
| 100 | 0:1 | 23.6 | 118–119 | KN |
| 30 | 0:1 | .. | ... | |

[a] OA = O-alkyloxime, Ox = oxime, AN = aldonitrone ($Ar_2CHN(O)CHAr$), KN = ketonitrone ($Ar_2CN(O)CH_2$-Ar). [b] Infrared spectrum superimposable on that of benzophenone oxime.

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[21] H. G. Hass and M. L. Bender, *J. Am. Chem. Soc.* **71**, 1767, 3482 (1949)

[22] Melting points are uncorrected. Analyses are by Spang Microanalytical Laboratory, Ann Arbor, Mich., or by Mrs. Anna Griffin, University of Michigan.

[23] U. W. Städel and H. Prätorius, *Ann.*, **194**, 307 (1878).

[24] E. B. Barnett and M. A. Mathews, *J. Chem. Soc.*, 767 (1924).

[25] F. Munchmeyer, *Ber.*, **20**, 510 (1887).

[26] O. Exner, *Chem. Listy*, **48**, 1634 (1954); *C. A.*, **49**, 14674 i (1955).

[27] A. Lachman, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 70.

TABLE VIII

ALKYL DERIVATIVES OF OXIMES

| Oxime[a] | M.p., °C. | Formula | Infrared spectrum, cm.$^{-1}$ |  |  |  | Carbon, % |  | Hydrogen, % |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | C–O ? | N–O ? | C–N ? | N → O ? | Calcd. | Found | Calcd. | Found |
| BzPh O-benzyl | 60–62 |  | 1040 | 970 |  |  |  |  |  |  |
| BzPh N-benzyl | 121–122 |  |  |  | 1200 | 1250 |  |  |  |  |
| BzH N-benzhydryl | 163–165 |  |  |  | 1130 | 1260 |  |  |  |  |
| BzPh O-*p*-Cl-benzyl | 101–102 | $C_{20}H_{16}ONCl$ | 1045 | 1000 |  |  | 74.64 | 74.62 | 5.01 | 5.06 |
| *p*-ClBzH H-benzhydryl[b] | 179–180 | $C_{20}H_{16}ONCl$ |  |  | 1140 | 1260 | 74.64 | 74.67 | 5.01 | 5.12 |
| BzPh O-*p*-NC-benzyl | 149–150 | $C_{21}H_{16}ON_2$ | 1040 | 990 |  |  | 80.75 | 80.57 | 5.16 | 5.24 |
| BzPh N-*p*-NC-benzyl[c] | 137–139 | $C_{21}H_{16}ON_2$ |  |  | 1190 | 1265 | 80.75 | 80.50 | 5.16 | 5.18 |
| *p*-NC-BzH N-benzhydryl | 152–153 | $C_{21}H_{16}ON_2$ |  |  | 1140 | 1270 | 80.75 | 80.76 | 5.16 | 5.27 |
| BzPh O-*p*-$CH_3O$-benzyl | 82–83 | $C_{21}H_{19}O_2N$ | 1045 | 970 |  |  | 79.47 | 79.55 | 6.03 | 5.98 |
| BzPh N-*p*-$CH_3O$-benzyl[d] | 79.5–80.5 | $C_{21}H_{19}O_2N$ |  |  | 1180 | 1280 | 79.47 | 79.26 | 6.03 | 5.92 |
| BzPh O-*p*-$CH_3$-benzyl | 77–78 | $C_{21}H_{19}ON$ | 1040 | 980 |  |  | 83.69 | 83.91 | 6.35 | 6.26 |
| BzPh N-*p*-$CH_3$-benzyl[e] | 93–94 | $C_{21}H_{19}ON$ |  |  | 1180 | 1280 | 83.69 | 83.83 | 6.35 | 6.53 |
| *p*-$CH_3$-BzH N-benzhydryl | 148–150 | $C_{21}H_{19}ON$ |  |  | 1140 | 1265 | 83.69 | 83.70 | 6.35 | 6.26 |
| BzPh O-*p*-$O_2N$-benzyl[f] | 125–126 | $C_{20}H_{16}O_3N$ | 1030 | 990 |  |  | 72.28 | 72.29 | 4.82 | 4.72 |
| *p*,*p*'-$Cl_2$BzPh O-benzyl | 90–91 | $C_{20}H_{15}ONCl_2$ | 1040 | 980 |  |  | 67.43 | 67.72 | 4.24 | 4.30 |
| *p*,*p*'-$Cl_2$BzPh N-benzyl[g] | 119–120 | $C_{20}H_{15}ONCl_2$ |  |  | 1170 | 1250 | 67.43 | 67.53 | 4.24 | 4.35 |
| *p*,*p*'-$(MeO)_2$BzPh O-benzyl | 62–63 | $C_{22}H_{21}O_3N$ | 1030 | 990 |  |  | 76.06 | 76.12 | 6.09 | 6.16 |
| *p*,*p*'-$(MeO)_2$BzPh N-benzyl[h] | 135–136 | $C_{22}H_{21}O_3N$ |  |  | 1130 | 1200 | 76.06 | 76.13 | 6.09 | 6.19 |
| *p*,*p*'-$(CH_3)_2$BzPh O-benzyl | 101–102 | $C_{22}H_{21}ON$ |  |  |  |  | 83.77 | 83.62 | 6.71 | 6.78 |
| *p*,*p*'-$(NO_2)_2$BzPh O-benzyl | 132–133 | $C_{20}H_{15}O_5N$ | 1010 | 975 |  |  | 63.66 | 63.55 | 4.01 | 4.03 |
| *p*,*p*'-$(NO_2)_2$BzPh N-benzyl[i] | 184–205 | $C_{20}H_{16}O_5N$ |  |  | 1145 | 1270 | 63.66 | 63.63 | 4.01 | 3.94 |
| *m*,*m*'-$(NO_2)_2$BzPh O-benzyl | 124–125 | $C_{20}H_{15}O_5N$ | 1040 | 1005 |  |  | 63.66 | 63.65 | 4.01 | 4.10 |
| *m*,*m*'-$(NO_2)_2$BzPh N-benzyl[j] | 143–144 | $C_{20}H_{15}O_5N$ |  |  | 1140 | 1260 | 63.66 | 63.58 | 4.01 | 4.18 |
| BzH N-*m*,*m*'-$(NO_2)_2$benzhydryl[k] | 137–140 |  |  |  | 1140 | 1270 |  |  |  |  |
| BzPh O-Me | 61–62 |  | 1050 | 980 |  |  |  |  |  |  |
| BzPh N-Me | 102–103 |  |  |  | 1160 | 1260 |  |  |  |  |
| *p*,*p*'-$Cl_2$BzPh O-Me | 90–91 | $C_{14}H_{11}ONCl_2$ | 1060 | 990 |  |  | 60.02 | 60.14 | 3.93 | 3.93 |
| *p*,*p*'-$Cl_2$BzPh N-Me | 117–118 | $C_{14}H_{11}ONCl_2$ |  |  | 1080 or 1180 | 1260 | 60.02 | 60.15 | 3.93 | 3.93 |
| *p*,*p*'-$(MeO)_2$BzPh O-Me | 84–85 | $C_{16}H_{17}O_3N$ | 1050 | 980 |  |  | 70.83 | 70.78 | 6.32 | 6.27 |
| *p*,*p*'-$(MeO)_2$BzPh N-Me | 94–95 | $C_{16}H_{17}O_3N$ |  |  | 1140 | 1190(?) | 70.83 | 70.65 | 6.32 | 6.19 |
| *p*,*p*'-$(NO_2)_2$BzPh O-Me | 150–152 | $C_{14}H_{11}O_5N$ | 1040 | 1000 |  |  | 55.81 | 55.83 | 3.68 | 3.75 |
| *p*,*p*'-$(NO_2)_2$BzPh N-Me | 213–214 | $C_{14}H_{11}O_5N$ |  |  | 1120 | 1260 | 55.81 | 55.84 | 3.68 | 3.66 |
| *m*,*m*'-$(NO_2)_2$BzPh O-Me | 125–126 | $C_{14}H_{11}O_5N$ | 1050 | 920 |  |  | 55.81 | 55.80 | 3.68 | 3.64 |
| *m*,*m*'-$(NO_2)_2$BzPh N-Me | 188–189 | $C_{14}H_{11}O_5N$ |  |  | 1160 | 1265 | 55.81 | 55.61 | 3.68 | 3.73 |

[a] BzPh = benzophenone; BzH = benzaldehyde. [b] Hydrolysis gave *p*-chlorobenzaldehyde, characterized as its phenylhydrazone, m.p. 121–122°. [c] Hydrolysis gave benzophenone, characterized as its 2,4-nitrophenylhydrazone, m.p. 235–236°.[31] [d] Hydrolysis gave benzophenone, characterized as its 2,4-nitrophenylhydrazone, m.p. 233–237°, mixed m.p. 234–238°.[32] [e] Hydrolysis gave benzophenone, characterized as its 2,4-dinitrophenylhydrazone, m.p. 233–234°.[32] [f] Hydrolysis gave *p*-nitrobenzyloxyamine hydrochloride, m.p. 116–117° (reported[7] m.p. 117°), and benzophenone, identified by infrared spectrum. [g] Hydrolysis gave *p*,*p*'-dichlorobenzophenone, m.p. 140–142° alone or mixed.[31] [h] Hydrolysis gave *p*,*p*'-dimethoxybenzophenone, m.p. 142–144° alone or mixed.[31] [i] Hydrolysis gave *p*,*p*'-dinitrobenzophenone, m.p. 183–184° alone or mixed. [j] Hydrolysis gave *m*,*m*'-dinitrobenzophenone, m.p. 155–156° alone or mixed. [k] M.p. and infrared spectrum markedly altered on recrystallization from chloroform, and compound then contained chlorine ($CHCl_3$ solvate?). *Anal.* Found: C, 50.77; H, 3.66; N, 9.17.

alent quantity of oxime to a solution of the metal ethoxide in ethanol. The tetramethylammonium salt was prepared by adding an equivalent quantity of tetramethylammonium bromide to a solution of the sodium salt in absolute ethanol, warming, cooling, and removing the precipitated sodium bromide by filtration. The oxime salt was used in ethanol solution without isolation, and thus was mixed with some sodium bromide.

**Alkylating Agents.**—Benzyl chloride, bromide, *p*-methylbenzyl bromide, *p*-nitrobenzyl bromide and methyl bromide were obtained from Eastman Organic Chemicals Co. Benzyl *p*-toluenesulfonate was prepared according to Koshi and Hammond,[28] and recrystallized from petroleum ether immediately before use. *p*-Chlorobenzyl chloride, Eastman yellow label grade, was distilled at 70.5–71° (2 mm.) and crystallized; m.p. 30.5–31° (reported[29] m.p. 29°). *p*-Cyanobenzyl bromide was prepared according to Case.[30] *p*-Methoxybenzyl bromide was prepared according to Kornblum, *et al.*,[2a] and used immediately.

**Alkylation Experiments.**—An alkali metal (0.0125 gram atom) was dissolved in 23 ml. of absolute alcohol, and followed by the equivalent quantity of powdered oxime. In some cases warming was necessary to dissolve all the oxime. At room temperature, 0.0125 mole of alkylating agent was added, alone if solid, or with a small rinse of absolute alcohol if liquid. Volume was adjusted to 25 ml. In the experiments with methyl bromide, the reagent was distilled into the reaction vessel in excess, over periods of 10 to 45 min. Some experiments were done in slightly larger or smaller scale, but conditions were otherwise the same. In the one case indicated, the solution was diluted to 20 times its original volume with absolute ethanol.

Alkylation of free benzophenone oxime was carried out by allowing a slurry of 2.46 g. (0.0125 mole) of powdered benzophenone oxime in 2.13 g. (0.0125 mole) of benzyl bromide to stand in the dark with protection from carbon dioxide and moisture for 75 days, and then heating it on a steam-bath for 3.5 days.

**Product Analysis.**—The reaction mixtures were evaporated to dryness, first in an air stream, and then by keeping under 0.05 mm. vacuum at room temperature for at least 12 hr. The residues were then extracted with carbon tetrachloride or chloroform to remove all organic products, and the residual salts were weighed and checked for complete water solubility; the weights were nearly all within 4% of the calculated. Tetramethylammonium bromide is slightly soluble in carbon tetrachloride, so its residual weight was not meaningful. Both the dinitrobenzophenone oximes were nearly insoluble in the extraction solvents, and were isolated from the residues, in a good state of purity as shown by m.p. and infrared spectra, by dissolving away the sodium bromide with water. In the case of the benzylation of free benzophenone oxime, the reaction mixture was washed with sodium bicarbonate solution and the organic substances

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(28) J. K. Kochi and G. S. Hammond, *J. Am. Chem. Soc.*, **75**, 3443 (1953).

(29) S. C. J. Olivier, *Rec. trav. chim.*, **41**, 307 (1922).

(30) F. H. Case, *J. Am. Chem. Soc.*, **47**, 1144 (1925).

(31) J. P. Picard and C. W. Kearns, *Can. J. Research*, **28B**, 56 (1950), report m.p. 144–145° for *p*,*p*'-dichloro- and 142–143° for *p*,*p*'-dimethoxybenzophenone.

(32) Reported m.p. 237°: R. L. Shriner and R. C. Fuson, "The Systematic Identification of Organic Compounds," John Wiley and Sons, Inc., New York, N. Y., 1948, p. 171.

taken up in benzene. The organic extracts were in all cases made up to fixed volumes, and aliquots were taken for analysis.

Chromatographic separations were done on 1-cm. diameter 42-cm. columns containing approximately 20 g. of fresh 60–100 mesh Florisil (Floridin Co., Tallahassee, Fla.). The columns were developed and eluted at an average flow rate of 4 ml. per min., using first carbon tetrachloride, then mixtures with chloroform in volume ratios of 9:1, 8:2, 7:3, 6:4, 1:1, and finally pure chloroform. The eluate was collected in fractions of 20 or 30 ml. in tared flasks. Each fraction was evaporated in a stream of filtered air and then dried *in vacuo* for at least 12 hr. before weighing the residues and determining their melting points. The order of elution was invariably O-alkyl oxime, ketone, oxime, aldonitrone and ketonitrone. Separations were in most cases sharp, except in the case of the nitrone tautomers, which usually showed some overlapping. When melting points were ambiguous or low, infrared spectra were used to establish identity or approximate purity. A typical experiment is shown in Table VII. The other essential information appears in Tables I–VI.

In a control analysis, a synthetic mixture of 304 mg. of benzophenone O-benzyloxime, 57 mg. of benzophenone N-benzyloxime and 57 mg. of benzaldehyde N-benzhydryloxime was treated in the foregoing manner. There were recovered 301, 57 and 52 mg., respectively; total recovery 98%.

**Alkyl Oximes.**—When sufficient O- or N-alkyl oxime was obtained from the chromatographic analyses, it was purified by recrystallization and characterized by melting point, analysis if previously unreported, infrared[33] spectrum (Nujol mull), and, for one of each pair of nitrones, hydrolysis. This information is summarized in Table VIII.

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[33] A Perkin–Elmer model 21 instrument was used.

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[CONTRIBUTION FROM THE CALIFORNIA RESEARCH CORPORATION, RICHMOND, CALIF.]

# Selective Hydrocracking of C$_9$- to C$_{12}$-Alkylcyclohexanes on Acidic Catalysts. Evidence for the Paring Reaction[1]

BY CLARK J. EGAN, G. E. LANGLOIS AND R. J. WHITE

RECEIVED AUGUST 28, 1961

With a nickel sulfide on silica–alumina or with a silica–alumina catalyst below about 300–350°, a C$_{10}$–C$_{12}$ alkylcyclohexane having *n* carbon atoms cracks selectively to form principally isobutane and a cycloalkane having *n*-4 carbon atoms. Structural isomers crack to give the same product distribution by carbon number. Under these cracking conditions, the cycloalkane ring is quite stable. For example, with polymethylcyclohexanes, a reaction occurs that, in its over-all effect, peels or pares methyl groups from the cycloalkane ring and eliminates them as branched alkanes without loss of ring structure. This reaction, which has been named the paring reaction, occurs more readily with cycloalkanes than with monocyclic aromatic hydrocarbons. A mechanism is proposed that involves a rapid isomerization to a common mixture of carbonium ions on the catalyst surface. This is followed by selective cracking at a slower rate of certain carbonium ions that have at least four carbons in a branched side chain.

## Introduction

Relatively few papers have been published on the catalytic cracking of cycloalkanes.[2–4] In these papers, either silica–zirconia–alumina or silica–alumina catalyst was used at 500°; no evidence of highly selective cracking reactions was reported. Similarly, relatively few papers have been published on the hydrocracking of cycloalkanes. Gault and Germain[5] report non-selective conversions of tri- and tetramethylcyclopentanes over a platinum–alumina catalyst at 300–350° in the presence of hydrogen. In contrast, the hydroisomerization of cycloalkanes over dual functional catalysts, such as nickel–silica–alumina, has been studied extensively as discussed in recent review articles.[6,7]

The unusual product distribution obtained in the hydrocracking of an aromatic hydrocarbon, hexamethylbenzene, over a nickel sulfide on silica–alumina catalyst was described recently.[8] It was shown that the principal products are lower molecular weight methylbenzenes and branched alkanes, particularly isobutane. A reaction occurs that, in effect, peels or pares methyl groups from the aromatic ring and eliminates them as branched alkanes with essentially no loss of ring structure. This reaction has been named the *paring reaction*.

This paper describes the behavior of alkylcyclohexanes containing at least three carbons in the side chain or side chains under certain hydrocracking conditions. It is shown that a paring reaction occurs with these cycloalkanes. This paring reaction forms lower molecular weight cycloalkanes and branched alkanes, principally isobutane with a high conservation of ring structure.

## Experimental

**Equipment.**—The experiments were performed in a continuous flow, fixed bed, microcatalytic unit. The 6 ml. of catalyst was supported inside a 0.79-cm. i.d. stainless steel tube 85 cm. in length which was surrounded by a heavy walled steel block inside an electrically heated oven. Catalyst temperatures were measured by a chromel–alumel thermocouple located on the reactor wall at the central portion of the catalyst bed. A Celectray controller was used to control the temperature.

Hydrocarbon feed rates were measured by means of a Microfeeder pump (Proportioneers, Inc.). The hydrogen rate was measured by oil displacement in a reservoir. The hydrogen used was more than 99.5 mole per cent. pure.

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[1] The term "paring" denotes a cracking reaction wherein the cyclic structure is preserved and wherein the predominant alkane product from cracking is isobutane.

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[4] N. A. Radzhabli-Seidova, S. I. Khromov, Ch. Dorzhin, E. S. Balenkova, E. G. Treshchova and B. A. Kazanskii, *ibid.*, **29**, 2219 (1959).

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[7] H. Pines and N. E. Hoffman in "Advances in Petroleum Chemistry and Refining," Vol. III, Interscience Publishers, Inc., New York, N. Y., 1960.

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