PART - II

STUDIES ON OXIDATIVE DEOXIMATION USING PYRIDINIUM FLUOROCHROMATE (PFC): MILD AND SELECTIVE DEPROTECTION OF ALDOXIMES AND STERICALLY UNHINDERED KETOXIMES WITH PFC ON WET ALUMINA SUPPORT; PFC IN COMBINATION WITH 30% H₂O₂ – AN EFFICIENT REAGENT FOR THE DEPROTECTION OF OXIMES
SECTION A

DEPROTECTION OF OXIMES BY ACID HYDROLYSIS, OXIDATION AND REDUCTION - A SURVEY
Protection of carbonyl compounds as oximes is of great importance to organic chemists, as these are readily prepared and highly stable compounds. Oximes are extensively used for purification and characterisation of carbonyl compounds and preparation of amides via Beckmann rearrangement. Since oximes can be prepared from noncarbonyl compounds, the regeneration of carbonyl compounds from oximes provides an alternative route to aldehydes and ketones. Therefore, the conversion of oximes to the corresponding carbonyl compounds has received much attention in recent years. Classically, acid hydrolysis of oximes was used as the method of deprotection. The plethora of reagents employed for the hydrolytic cleavage of the carbon-nitrogen double bond of oximes include phthalic anhydride-water, H\textsuperscript{+}/pyruvic acid, aqueous oxalic acid, nitrous acid, levulinic acid – aqueous hydrochloric acid, hydrochloric acid – formaldehyde, aqueous acetic acid, sodium hydrogen sulphite and DOWEX-50.

Since most of these methods exclude acid-sensitive aldehydes and ketones, a variety of oxidative and reductive procedures have been developed over the years. The oxidizing agents employed for deoximation include lead (IV) acetate, ozone, cerium (IV) ammonium nitrate, thallium (III) nitrate, chromium (VI) oxide in the form of Jones and Collins reagent, bis(triphenylphosphine) palladium/oxygen, nitronium and nitrosonium salts, nitrosochloride-pyridine, Barton’s reagent, bromine, alkaline hydrogen peroxide, periodic acid, sodium nitrite, pyridinium chlorochromate (PCC), thallium (III) acetate, PCC and hydrogen peroxide, bis(pyridinesilver)-permanganate, cetyltrimethylammonium permanganate (CTAP), (diacetoxyiodo)benzene, chromyl chloride, potassium bromate, dinitrogen tetroxide, triethylammonium chlorochromate, chromic anhydride-chlorotrimethylsilane, dimethyldioxirane, t-butyl hydroperoxide, TS-1-H\textsubscript{2}O\textsubscript{2} combination, sodium perborate, chlorotrimethylsilane and sodium nitrite, manganese (III) acetate, Dess-Martin periodinane, peroxymonosulphate ion, dimethylammonium chlorochromate adsorbed on alumina.
Reductive procedures converting the oxime moiety to imine function and its subsequent hydrolysis (pH ~5) to carbonyl group have been explored as well. Raney nickel in alkaline solution, zinc in acetic acid, iron pentacarbonyl, chromous acetate, aluminium isopropoxide, titanium (III) chloride have been also employed. It has been observed that reductive fission of carbon-nitrogen double bond of hindered oximes is usually difficult for catalytic reductions because of the inaccessibility of the metal surface to the hindered oxime group. For such cases, reduction under homogeneous condition was more successful.

Recently, deoximation under microwave irradiation has been successfully developed for a number of reagents. Uses of catalytic amount of bismuth (III) trichloride in THF, ammonium persulphate adsorbed on silica and sodium bismuthate adsorbed on wet alumina deserve mention in this connection. Here we discuss salient features of some of the more recent methods of deoximation which have been found to be manipulatively simple, selective and efficient.

1. Chlorotrimethylsilane (TMSCl) and Sodium Nitrite

TMSCl and sodium nitrite (in 2:1 molar ratio) alongwith phase transfer catalysts in CCl₄ has been found to be an efficient deoximating reagent. Benzyl triethylammonium chloride or Aliquat 336 has been used to facilitate the solubilization of NaNO₂ in CCl₄. The reaction involves nitrosyl chloride (Scheme 1).

\[
\begin{align*}
\text{TMSCl} + \text{NO}_2^- & \rightarrow \text{TMS-O-N}=\text{O} + \text{Cl}^- \\
\text{TMS-O-N}=\text{O} + \text{TMSCl} & \rightarrow \text{TMS-O-TMS} + \text{ClN}=\text{O} \\
>\text{C}=\text{N-OH} + \text{NOCI} & \rightarrow >\text{C}=\text{N-NO} + \text{Cl}^- \\
>\text{C}=\text{N-OH} + \text{Cl}^- & \rightarrow >\text{C}=\text{O} + \text{N}_2\text{O} + \text{HCl}
\end{align*}
\]

\(\text{R}^1\text{C}=\text{N-OH} \xrightarrow{\text{TMSCl, NaNO}_2} \text{CCl}_4, 3-5 \text{ h} \xrightarrow{\text{R}^1} >\text{C}=\text{O} \quad (88-98\%)\)

**Scheme 1**: Mechanism of deoximation with chlorotrimethylsilane and sodium nitrite.
Oxime Yield of carbonyl compound (%)

<table>
<thead>
<tr>
<th>Oxime</th>
<th>Yield of carbonyl compound (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = Ph, R&lt;sub&gt;2&lt;/sub&gt; = H</td>
<td>95</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = p-MeOPh, R&lt;sub&gt;2&lt;/sub&gt; = H</td>
<td>97</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = Me&lt;sub&gt;3&lt;/sub&gt;C, R&lt;sub&gt;2&lt;/sub&gt; = Me</td>
<td>85</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = Ph, R&lt;sub&gt;2&lt;/sub&gt; = Me</td>
<td>97</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = R&lt;sub&gt;2&lt;/sub&gt; = H</td>
<td>98</td>
</tr>
</tbody>
</table>

The salient features of this method are as follows:

1) Both aldoximes and ketoximes were deoximated without major side-reactions in high yields. However, the yields were a little lower for aliphatic aldoximes.

2) Oximes of α,β-unsaturated carbonyl compounds (e.g. cinnamaldehyde oxime) were not successfully deoximated.

2. t-Butyl hydroperoxide<sup>36</sup>

![Chemical Reaction](image)

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Yield of carbonyl compound (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = Ph, R&lt;sub&gt;2&lt;/sub&gt; = Me</td>
<td>80</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = p-NO&lt;sub&gt;2&lt;/sub&gt;, R&lt;sub&gt;2&lt;/sub&gt; = Me</td>
<td>70.3</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = p-MeOPh, R&lt;sub&gt;2&lt;/sub&gt; = H</td>
<td>30</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = R&lt;sub&gt;2&lt;/sub&gt; = Ph</td>
<td>98</td>
</tr>
<tr>
<td>R&lt;sub&gt;1&lt;/sub&gt; = p-MeOPh, R&lt;sub&gt;2&lt;/sub&gt; = Ph</td>
<td>100</td>
</tr>
</tbody>
</table>

The main disadvantage of this method is the prolonged reaction time required particularly for sterically hindered oxides e.g. camphor oxime (18 h), 1-tetralone oxime (18 h). α,β-unsaturated aldoximes also react slowly.
3. Dimethyldioxirane$^{35}$

This method is particularly effective for aliphatic ketoximes (reaction time : 5 min to 1 h). In contrast, the reaction of aromatic ketoximes with dimethyldioxirane at room temperature usually took 24 to 48 h for completion. This method is not useful for unsaturated oximes. 3-methyl-2-cyclohexenone, 5-hexen-2-one gave mixtures of parent ketones and the overoxidized epoxyketones in low yields (< 30%). Similar oxidation of aldoximes failed even after prolonged reaction time e.g. benzaldehyde oxime did not react at room temperature for 24 h. Some illustrative examples are cited below.

<table>
<thead>
<tr>
<th>Oxime</th>
<th>Reaction time</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Methylcyclohexanone oxime</td>
<td>30 min</td>
<td>80</td>
</tr>
<tr>
<td>4-t-Butylcyclohexanone</td>
<td>30 min</td>
<td>98</td>
</tr>
<tr>
<td>Norbornanone oxime</td>
<td>1 h</td>
<td>85</td>
</tr>
<tr>
<td>Acetophenone oxime</td>
<td>24 h</td>
<td>95</td>
</tr>
<tr>
<td>1-Tetralone oxime</td>
<td>24 h</td>
<td>100</td>
</tr>
</tbody>
</table>

4. Dess-Martin Periodinane$^{41}$

This method based on Dess-Martin Periodinane (DMP), 1,1,1-triacetoxy-1,1-dihydro-1,2-benziodoxo-3(1H)one, is reported to be a very fast demasking process for aliphatic, aromatic aldoximes and ketoximes.
Oximes

Acetophenone oxime
4-Nitroacetophenone
Benzil monoxime
Cyclohexanone oxime
Camphor oxime

Yields of carbonyl compounds (%)
94
96
100
98
94

Aldoximes gave some other products in addition to regenerated aldehydes. The proposed route of deoximation is shown below (Scheme 2):

Scheme 2: Mechanism of deoximation with Dess-Martin periodinane.

5. Sodium bismuthate supported on wet alumina under microwave irradiation

Wet silica gel was found to be a very efficient solid support for sodium bismuthate as the deoximating reagent. The optimum molar ratio of the substrate to the reagent was found to be 1:2. By conventional heating method, this reagent was not effective even after 24 h. The reagent has wide applicability for deoximation of aliphatic, aromatic ketoximes.
and dioximes of α- and β-diketones. However, the deoximation of aldoximes under similar reaction conditions resulted in the formation of complex mixture of products.

<table>
<thead>
<tr>
<th>Oxime</th>
<th>Time (min)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclohexanone oxime</td>
<td>5</td>
<td>73</td>
</tr>
<tr>
<td>Acetophenone oxime</td>
<td>1</td>
<td>89</td>
</tr>
<tr>
<td>Benzophenone oxime</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>Benzil dioxime</td>
<td>3</td>
<td>88</td>
</tr>
<tr>
<td>6-Methoxytetralone oxime</td>
<td>3</td>
<td>88</td>
</tr>
<tr>
<td>2-Naphthyl methyl ketone oxime</td>
<td>1</td>
<td>90</td>
</tr>
</tbody>
</table>

6. **Bismuth trichloride catalysed cleavage of oximes under microwave irradiation**

Microwave-assisted cleavage of oximes to parent carbonyl compounds using catalytic amount of BiCl₃ has been developed. The method is fast and requires 0.1 equivalent of BiCl₃. Even sterically hindered ketoximes (camphor oxime) was demasked in high yield. The results of some representative conversions are shown below.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Time (min)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetophenone oxime</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>Camphor oxime</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>Benzophenone oxime</td>
<td>2</td>
<td>96</td>
</tr>
<tr>
<td>4-Chlorobenzaldehyde oxime</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>Cinnamaldehyde oxime</td>
<td>5</td>
<td>45 and decomposition products</td>
</tr>
</tbody>
</table>

7. **Chromous acetate-based reductive deoximation**

Chromous acetate causes reductive fission of the oxime N-O linkage to give an imine which then suffers rapid hydrolysis to ketone at the pH (~ 5) of the acetate buffered solution.
Substrate | Conditions | Yield (\%) 
--- | --- | --- 
Cyclohexanone oxime | 4.5 h (65°) | 84 
Phenylacetone oxime | 16 h (65°) | 74 
Camphor oxime | 11 h (65°) | 88 
Progesterone-20-monoxime O-acetate | 24 h (25°) | 84 
1,4-Cyclohexanedione-monohemithioethylene ketal | 10 h (65°) | 92 
4-Benzoyloxy cyclohexanone | 7 h (65°) | 95 

The order of reactivity is opposite to that of acid-catalysed hydrolysis, which is known to be especially slow for conjugated oximes. Also, acid- and base-sensitive functional groups, such as ketal, hemithioketal, ester and epoxide were not affected in this deoximation process. Interestingly, free ketoxydes were only slowly converted to ketones. Aldoximes and ketoxydes displayed differential reactivity, for example, the 3-acetoxy function in progestrone 3,20-bis-O-acetoxyde is selectively hydrolysed.

8. Dowex-50 based deoximation of ketoxydes

Dowex-50 is a cation exchange resin which can efficiently deoximate ketoxydes in an aqueous suspension at reflux temperature. The yields are good for ketoxydes of \( \beta \)-ketoesters. However, this method does not work for aldoximes.
<table>
<thead>
<tr>
<th>Oximes</th>
<th>Refluxing time (h)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclohexanone oxime</td>
<td>2</td>
<td>87</td>
</tr>
<tr>
<td>Acetophenone oxime</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>Indanone oxime</td>
<td>2</td>
<td>85</td>
</tr>
<tr>
<td>Benzophenone oxime</td>
<td>2</td>
<td>85</td>
</tr>
<tr>
<td>Ethyl 2-oxacyclohexane-carboxylate oxime</td>
<td>3</td>
<td>74</td>
</tr>
<tr>
<td>Hagemann’s ester oxime</td>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>Benzaldehyde oxime</td>
<td>5</td>
<td>32</td>
</tr>
<tr>
<td>m-Methoxybenzaldehyde oxime</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>Citral oxime</td>
<td>8</td>
<td>No reaction</td>
</tr>
</tbody>
</table>

This method is chemoselective for ketoximes and selective deblocking of a ketone in the presence of an aldehyde is possible, as in the following dicarbonyl compound:
SECTION B

PYRIDINIUM FLUOROCHROMATE SUPPORTED ON WET ALUMINA: A MILD EFFICIENT REAGENT FOR THE OXIDATIVE DEOXIMATION OF ALDOXIMES AND STERICALLY UNHINDERED KETOXIMES
Oxidation of oximes to the parent carbonyl compounds constitutes a very useful functional group transformation and the plethora of reagents developed for this conversion directly attest to its importance. However, many of these procedures have serious limitations e.g. use of reagents which are either hazardous or not so readily available, formation of overoxidation products, particularly for aldoximes, lack of selectivity towards aldoximes and ketoximes. It is also noteworthy that a good number of reagents are quite efficient for demasking ketoximes but do not work for aldoximes. This interested us to develop a mild, efficient methodology for deoximation involving simple operations and a cheap reagent. We also felt the need for a reagent with a bias for aldoximes so that it can used to discriminate aldoximes from ketoximes.

Chromium (VI) oxidants are known to serve organic chemists considerably and have undergone remarkable improvement over the years to suit the needs of practicing chemists. Pyridinium chlorochromate (PCC), pyridinium dichromate (PDC), pyridinium fluorochromate (PFC) and, quite recently, quinolinium fluorochromate (QFC) have figured as most significant oxochromium (VI) oxidants. To the best of our knowledge, the potential of PFC as a reagent for deoximation has not been explored as yet and we wished to develop it for selective deoximation of aldoximes. PFC has proved to be a very effective oxo-transfer agent. This chromium (VI) species is as reactive as PCC and is known to oxidize alcohols to carbonyl compounds without overoxidation. Interestingly, oxidation of primary and benzylic alcohols to the corresponding aldehydes with PFC is reported to occur without concomitant oxidation of the products to the acids. Another very important aspect of this reagent is that it is less acidic than PCC, which has been more widely used as an oxidant. The pH values of 0.01 M aqueous solutions of PCC and PFC are 1.75 and 2.45 respectively, showing its reduced acidity (pKa values of PCC and PFC are 1.4 and 2.7 respectively). Consequently, PFC can be used for even acid-labile compounds such as trityl ethers or dimethyl t-butyldimethylsilyl (DMTBS) ethers without buffering the reaction mixture with bases. PFC is soluble in common organic solvents such as acetone, methylene chloride, dimethylformamide and tetrahydrofuran. However, the important limitations of this reagent, like other...
oxochromium (VI) oxidants, is the release of toxic reduced chromium (IV) species in the environment and the problems encountered in the isolation of products entrapped in it. We planned to circumvent these problems by using PFC on a solid inorganic support. We found that wet alumina containing about 1 mmol of PFC per gram was a suitable reagent for such purpose. This makes the use of PFC more environmentally benign and at the same time there was no problem of isolation of the products because the reduced chromium species was firmly fixed in the alumina. Herein we describe a simple mild methodology of oxidative deoximation using PFC adsorbed on wet alumina. This method has been found to be very efficient for a wide variety of aldoximes and sterically unhindered ketoximes. The results of our investigations are summarized in Table 1.

\[
\begin{array}{c}
R^1 \underset{\text{C=N-OH}}{\xrightarrow{\text{PFC on wet alumina}}} \text{R}^1 \underset{\text{C=O}}{\xrightarrow{\text{R}^2}}
\end{array}
\]

Table 1. Oxidative deoximation with PFC on wet alumina support

<table>
<thead>
<tr>
<th>Entry</th>
<th>Oxime</th>
<th>Reaction time</th>
<th>Yield* of carbonyl compound (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>syn-Benzaldehyde oxime</td>
<td>20 min (20 min\textsuperscript{b})</td>
<td>90 (80\textsuperscript{b})</td>
</tr>
<tr>
<td>2.</td>
<td>2-Methoxybenzaldehyde oxime</td>
<td>10 min (10 min)</td>
<td>88 (76)</td>
</tr>
<tr>
<td>3.</td>
<td>2,4-Dimethoxybenzaldehyde oxime</td>
<td>10 min (15 min)</td>
<td>84 (70)</td>
</tr>
<tr>
<td>4.</td>
<td>4-Dimethylaminobenzaldehyde oxime</td>
<td>10 min (15 min)</td>
<td>86 (70)</td>
</tr>
<tr>
<td>5.</td>
<td>4-Nitrobenzaldehyde oxime</td>
<td>8 h</td>
<td>76</td>
</tr>
<tr>
<td>6.</td>
<td>2-Furfuraldehyde oxime</td>
<td>30 min (45 min)</td>
<td>96 (82)</td>
</tr>
<tr>
<td>7.</td>
<td>Citral oxime</td>
<td>30 min (45 min)</td>
<td>98 (78)</td>
</tr>
<tr>
<td>8.</td>
<td>Acetophenone oxime</td>
<td>6 h</td>
<td>92</td>
</tr>
<tr>
<td>9.</td>
<td>Cinnamaldehyde oxime</td>
<td>5 h</td>
<td>90</td>
</tr>
<tr>
<td>10.</td>
<td>Benzophenone oxime</td>
<td>7 h</td>
<td>80</td>
</tr>
<tr>
<td>Entry</td>
<td>Oxime</td>
<td>Reaction time</td>
<td>Yield* of carbonyl compound (%)</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------</td>
<td>---------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>11.</td>
<td>(a) Z-Benzil monoxime</td>
<td>9 h</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>(b) E-Benzil monoxime</td>
<td>7 h</td>
<td>82</td>
</tr>
<tr>
<td>12.</td>
<td>Cyclohexanone oxime</td>
<td>10 h</td>
<td>84</td>
</tr>
<tr>
<td>13.</td>
<td>Cyclopentanone oxime</td>
<td>10 h</td>
<td>80</td>
</tr>
<tr>
<td>14.</td>
<td>Ethylmethyl ketone oxime</td>
<td>1 h</td>
<td>98</td>
</tr>
<tr>
<td>15.</td>
<td>Isobutyl methyl ketone oxime</td>
<td>1.5 h</td>
<td>94</td>
</tr>
<tr>
<td>16.</td>
<td>t-Butyl methyl ketone oxime</td>
<td>4 h</td>
<td>86</td>
</tr>
<tr>
<td>17.</td>
<td>Camphor oxime</td>
<td>36 h</td>
<td>no reaction</td>
</tr>
<tr>
<td>18.</td>
<td>1-Tetralone oxime</td>
<td>36 h</td>
<td>no reaction</td>
</tr>
<tr>
<td>19.</td>
<td>Hagemann’s ester oxime</td>
<td>36 h</td>
<td>no reaction</td>
</tr>
<tr>
<td></td>
<td>(4-Carbethoxy-3-methyl-2-cyclohexen-1-one oxime)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Yields refer to those of pure isolated products, fully characterized by spectral data, m.m.p. and co-TLC with authentic sample.

Values in parenthesis indicate reaction times and yields when the reaction was carried under homogeneous conditions.

The salient features of this method, as revealed from the above results, are as follows.

1) Aryl aldoximes, particularly those bearing electron-releasing groups (OMe, NMe$_2$), underwent facile deoximation (entries 1-4).

2) Electron-withdrawing group, as in 4-nitrobenzaldehyde oxime, hindered the cleavage of carbon-nitrogen double bond (entry 5).

3) The regeneration of aldehydes took place without any overoxidation.

4) Oxidative cleavage of the carbon-nitrogen double bond in the presence of conjugated carbon-carbon double bond, as in the case of cinnamaldehyde oxime, occurred selectively. Similarly, unconjugated carbon-carbon double bond of citral oxime was not affected during the cleavage of oxime. It is also remarkable that citral which is sensitive to acid-catalysed rearrangements$^{54}$ remained unaffected after being regenerated during the deoximation process. Also, oxime of acid-sensitive 2-furfural
(entry 6) was easily cleaved without overoxidation. These examples amply 
demonstrate the mildness of the reagent.

5) Aryl ketoximes, in general, displayed lower level of reactivity towards PFC on wet 
alumina and took longer reaction times (entries 10-11). Cyclic ketoximes, such as 
cyclohexanone oxime and cyclopentanone oxime (entries 12, 13) similarly took 
longer reaction times. This reactivity differential may be of potential use of 
discriminate aldoximes from ketoximes in a substrate containing both the moieties.

6) Aliphatic ketoximes were demasked with relative ease (entries 14-16) and a steric 
effect was evident.

7) This reagent was unsuccessful for the deoximation of benzoin oxime where benzil 
was isolated as the sole product of oxidation. With sterically hindered ketoximes e.g. 
camphor oxime, 1-tetralone oxime (entries 17, 18), no deoximation was observed 
even after prolonged exposure (36 h) to the reagent. An important structural 
constraint of this deoximation process also became evident in the case of oxime of 
Hagemann’s ester which has a vinylogous ester function to the keto carbonyl group. 
This oxime (entry 19) was resistant to the reagent even after 36 h.

8) Z-Benzil monoxime where the benzoyl group can engage in hydrogen bonding with 
\_syn-hydroxy group reacted at a considerable slower rate than the corresponding E- 
oxime. This observation suggests that the presence of a free hydroxy group is 
required for successful deoximation. This is also supported by the observations that 
acetophenone O-methyl oxime and acetophenone oxime O-acetate did not react with 
the reagent (48 h).

9) Interestingly, attempts at similar oxidation of aryl aldoximes with PFC under 
homogeneous conditions (in acetone solution) led to some overoxidation to 
carboxylic acids and consequently lower yields of aldehydes were obtained. Short 
reaction time and non-aqueous work-up presumably allowed acid-sensitive 
molecules to be handled more efficiently when surface-mediated protocol was used.

10) This method also compared favourably in respect of reaction times and yields with 
other oxochromium (VI) reagents employed for this purpose. For example, 
benzaldoxime afforded benzaldehyde in 56% yield (15 h) with pyridinium 
chlorochromate\(^{24}\), in 35% yield with pyridinium chlorochromate and 30% hydrogen
peroxide\textsuperscript{26}, in 72\% yield (10 min) with trimethylsilyl chlorochromate\textsuperscript{34} and in 45\% yield (2 h) with dimethyldichlorosilane and chromium trioxide\textsuperscript{34}.

11) Exposure of an equimolar mixture of benzaldoxime and benzophenone oxime to 2 mol equivalents of the reagent led, after 20 min, to almost quantitative recovery of unreacted benzophenone oxime along with benzaldehyde in 88\% yield. This model experiment demonstrates that this protocol has the merit of differentiating aldoximes from ketoximes in generating carbonyl compounds.

12) Use of 2 mol equivalents of PFC (one mmol adsorbed on 1 g of alumina) was found to be the optimized reaction condition that gave excellent yields. Use of a higher excess of the reagent and longer reaction time gave lower yields due to overoxidation.

Mechanistically, the cleavage process is initiated by nucleophilic attack of oxime hydroxy group on the fluorochromate anion to form the intermediate 1a (Scheme 3). The enhanced nucleophilicity of oximes or oximate anions due to $\alpha$-effect\textsuperscript{59} definitely favours this process. However, the formation of chromate ester 1a in this case has a significant difference from similar reactions in cases of primary and secondary alcohols with PFC. Whereas the chromate ester formation of primary and secondary alcohols with PFC\textsuperscript{60} is insensitive to electronic effects, the chromate ester formation of oxime is expected to be subject to electronic control due to conjugation of oxygen lone pair with the aromatic ring. Subsequent mode of cleavage of the chromate ester 1a presumably also depends on degree of electron release by the aromatic system. The intermediacy of a stabilized carbocation intermediate 1b followed by nucleophilic attack of water as such or hydroxide ion attached to alumina surface\textsuperscript{58} to form 1d seems to be a plausible route (route $a$) of cleavage of aryl oximes with electron – releasing substituents in ortho/para positions in the aromatic ring. However, this route of cleavage is unlikely or less likely for $p$-nitrobenzaldehyde oxime where the carbocation 1b formation is disfavoured. We propose that the decomposition of 1a to the carbonyl compound, in this case, occurs by 2,3-sigmatropic shift to 1c followed by nucleophilic attack of water on chromium (IV) species in a manner analogous to the mechanistic pathway\textsuperscript{20} proposed in the deoximation with benzeneseleninic anhydride. This step involves conversion of the $sp^2$ carbon of the
carbon-nitrogen bond to more sterically congested $sp^3$ hybridized state and is, therefore, subject to steric retardation.

Scheme 3: Plausible mechanism of deoximation with PFC on wet alumina support.

To summarize, we have developed a simple methodology for oxidative deprotection of oximes using PFC on wet alumina support. The advantage of this method is that it provides for rapid and efficient deoximation of aldoximes without overoxidation. The yields of carbonyl compounds are good-to-excellent (76-98%) for a wide variety of aldoximes and sterically unhindered aliphatic ketoximes. Aryl ketoximes are less rapidly cleaved which may be utilized for selective cleavage of aldoximes in the presence of former. However, this method does not work for the deoximation of sterically hindered ketoximes such as camphor oxime, 1-tetralone oxime and one with vinylogous ester moiety, such as Hagemann's ester oxime.

This work has been published recently: N.C. Ganguly, P. De, A.K. Sukai and S. De Synth Commun. 2002, 32(1), 1-8 (Annexure 2).
SECTION C

OXIDATIVE DEOXIMATION USING PYRIDINIUM FLUOROCHROMATE AND 30% HYDROGEN PEROXIDE
The cleavage of aldoximes and sterically unhindered ketoximes with PFC on wet alumina support excludes sterically congested ketoximes e.g. camphor oxime, 1-tetralone oxime and α,β-unsaturated ketoximes with vinylogous ester moiety e.g. Hagemann's ester oxime (4-carbethoxy-3-methyl-2-cyclohexen-1-one oxime). The scope of the method was, therefore, limited and we wished to develop a more general method of deoximation applicable for aldoximes as well as ketoximes. Our attention was drawn to the reported\(^{63}\) formation of diperoxo oxochromium (VI) species \([\text{Cr}^{VI}(\text{O}_2)_2\text{OH}]^{\ominus}\) by treatment of hydrogen peroxide upon potassium or ammonium dichromate in neutral or slightly acidic medium. By analogy, we envisaged that such strongly oxidizing species would be generated by the action of 30% H\(_2\)O\(_2\) and it might be an ideal reagent for the purpose of general deoximation. We, therefore, investigated the cleavage of a wide variety of aldoximes and ketoximes with this reagent. The oximes included aliphatic, aryl and cyclic aldoximes and ketoximes with varying structural and steric parameters. The results of these experiments are presented in Table 2.

Table 2. Regeneration of carbonyl compounds from oximes with PFC and 30% H\(_2\)O\(_2\)

<table>
<thead>
<tr>
<th>Entry</th>
<th>Oxime</th>
<th>Reaction time</th>
<th>Yield(^{a}) of carbonyl compound (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>syn-Benzaldehyde oxime</td>
<td>20 min</td>
<td>74 (83(^{b}))</td>
</tr>
<tr>
<td>2.</td>
<td>2-Methoxybenzaldehyde oxime</td>
<td>10 min</td>
<td>64 (86)</td>
</tr>
<tr>
<td>3.</td>
<td>2,4-Dimethoxybenzaldehyde oxime</td>
<td>10 min</td>
<td>54 (89)</td>
</tr>
<tr>
<td>4.</td>
<td>4-Dimethylaminobenzaldehyde oxime</td>
<td>10 min</td>
<td>68 (90)</td>
</tr>
<tr>
<td>5.</td>
<td>3,4-Methylenedioxybenzaldehyde oxime</td>
<td>15 min</td>
<td>70 (80)</td>
</tr>
<tr>
<td>6.</td>
<td>Citral oxime</td>
<td>15 min</td>
<td>78 (95)</td>
</tr>
<tr>
<td>7.</td>
<td>Isobutyl methyl ketone oxime</td>
<td>20 min</td>
<td>98</td>
</tr>
<tr>
<td>8.</td>
<td>(t)-Butyl methyl ketone oxime</td>
<td>1.5 h</td>
<td>97</td>
</tr>
<tr>
<td>9.</td>
<td>4-Nitrobenzaldehyde oxime</td>
<td>5 h</td>
<td>89</td>
</tr>
<tr>
<td>No.</td>
<td>Compound</td>
<td>Time</td>
<td>Yield (%)</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------------------------</td>
<td>-------</td>
<td>-----------</td>
</tr>
<tr>
<td>10.</td>
<td>Mesityl oxide oxime</td>
<td>4 h</td>
<td>92</td>
</tr>
<tr>
<td>11.</td>
<td>Acetophenone oxime</td>
<td>4 h</td>
<td>92</td>
</tr>
<tr>
<td>12.</td>
<td>2-Chloroacetophenone oxime</td>
<td>6 h</td>
<td>94</td>
</tr>
<tr>
<td>13.</td>
<td>Cinnamaldehyde oxime</td>
<td>3 h</td>
<td>88</td>
</tr>
<tr>
<td>14.</td>
<td>Benzophenone oxime</td>
<td>5 h</td>
<td>98</td>
</tr>
<tr>
<td>15.</td>
<td>1-Indanone oxime</td>
<td>6.5 h</td>
<td>90</td>
</tr>
<tr>
<td>16.</td>
<td>(a) Z-Benzil monoxime</td>
<td>6 h</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>(b) E-Benzil monoxime</td>
<td>4 h</td>
<td>92</td>
</tr>
<tr>
<td>17.</td>
<td>Cyclohexanone oxime</td>
<td>4 h</td>
<td>98</td>
</tr>
<tr>
<td>18.</td>
<td>Cyclopentanone oxime</td>
<td>2.5 h</td>
<td>96</td>
</tr>
<tr>
<td>19.</td>
<td>1-Tetralone oxime</td>
<td>24 h (18 h°)</td>
<td>78 (92°)</td>
</tr>
<tr>
<td>20.</td>
<td>Camphor oxime</td>
<td>30 h (20 h°)</td>
<td>88 (96°)</td>
</tr>
<tr>
<td>21.</td>
<td>4-Carbethoxy-3-methyl-2-cyclohexen-1-one oxime (Hagemann’s ester oxime)</td>
<td>8 h</td>
<td>86</td>
</tr>
</tbody>
</table>

*a* Yields refer to chromatographically pure compounds; the products were fully characterized by their physical properties (mp/bp), spectral data (IR, ¹H NMR) and comparison with authentic sample.  
*b* The reactions were carried out at -10° with slow addition of 30% H₂O₂ over a longer period.  
*c* Reagent for deoximation: PFC (4 mmol) and 30% H₂O₂ (1 ml) per mmol of substrate at ambient temperature.  

Cleavage of aldoximes and aliphatic ketoximes (entries 1-7) to carbonyl compounds was remarkably fast. Some retardation in the rate of cleavage was evident for t-butyl methyl ketone oxime due to the steric factor. However, substantial overoxidation to the corresponding carboxylic acids (10-30%) was observed for aldoximes, particularly for those with electron-releasing ortho/para substituents (entries 1-6). To minimize overoxidation, slow addition of 30% H₂O₂ to the mixture of oxime and PFC at -10° was found to be effective and this was reflected in the improvement in the yields of the regenerated carbonyl compounds by this procedure. Aromatic ketoximes and conjugated oximes displayed lower levels of reactivity and required longer reaction times. The optimized reaction condition for the deoximation of 1 mmol of oxime required 2 mmol of
PFC and 0.5 ml of 30% H$_2$O$_2$. However, this condition led only to slow deprotection of sterically hindered oximes, such as 1-tetralone oxime and camphor oxime. Addition of an extra amount of the reagent (4 mol equivalent of PFC and 1 ml of 30% H$_2$O$_2$) improved the yield and substantially shortened the reaction time (entries 19, 20). Cleavage of the carbon-nitrogen double bonds occurred selectively in the presence of unconjugated and conjugated carbon-carbon double bonds (entries 6 and 10 respectively). The reagent was also compatible with ester (entry 21) and methylenedioxy functions (entry 5). The presence of electron-withdrawing nitro group in the para position to the oxime (entry 9) deactivates the substrate. The substantial reactivity differential of aldoximes and ketoximes is potentially useful for chemoselective deprotection where both the moieties exist. We subjected an equimolar mixture of syn-benzaldehyde oxime and benzophenone oxime to the reagent (2 mol eq. of PFC, 0.5 ml of 30% H$_2$O$_2$, at $-10^\circ$ for 20 min) and isolated benzaldehyde and unreacted benzophenone oxime only. The slower deprotection of Z-benzilmonoxime in comparison with its diastereoisomer E-benzilmonoxime also revealed that the presence of free oxime hydroxy group is required for initial chromate ester formation which subsequently underwent decomposition to the ketone. The failure of acetophenone O-methyl oxime to react further confirmed this view.

We presume, by analogy, that the oxidizing species responsible for deoximation is a diperoxo oxochromium (VI) species 2a formed by the action of 30% H$_2$O$_2$ on PFC. 2a is involved with hydroxyl group of oxime to form a chromate ester intermediate 2b. We suggest that the formation of chromate ester intermediate should be subject to electronic control exerted by substituents in the aromatic ring on the lone pair of the oxygen atom of oxime group. Subsequent cleavage of 2b is presumably triggered by the nucleophilic attack of hydroperoxide anion, $^\cdot$OOH on electrophilic carbon of C=N. Enhanced nucleophilicity of $^\cdot$OOH over H$_2$O seems to favour this process (route a). However, electrophilic addition of an oxygen atom from one of the two peroxy groups of 2b to carbon-nitrogen double bond to form an oxaziridine 2c species cannot be ruled out (route b). 2c undergoes subsequent fragmentation to carbonyl compound. In fact, the formation of oxaziridine intermediate has been suggested for the oxidative cleavage of oximes with t-butyl hydroperoxide to carbonyl compounds (Scheme 4).
In conclusion, a new simple and effective method of deoximation has been developed. This method is complementary to the one earlier developed by us using PFC on wet alumina support. This method has wide scope and the reagents used are readily available and inexpensive. The manipulative simplicity of the method is also an attractive feature of this method. In view of above, we hope this new simple method will be a method of choice for deprotection of aldoximes as well as ketoximes.

This work has been published recently: N.C. Ganguly, A.K. Sukai, S. De and P. De. 
SECTION D

EXPERIMENTAL
Preparation of oximes as substrates for deoximation reactions

Oximes were generally prepared following the procedures described in the literature\cite{62a,b}. Their formation was detected by their relatively higher polar nature (lower Rf values) in comparison with starting aldehydes and ketones. Oximes were characterized by their mps and IR stretching frequencies in the range 1620-1700 cm\(^{-1}\) (C=\(\text{N}\) stretching) and 3150-3300 cm\(^{-1}\) (broad O-H stretching). For water-soluble aldehydes and ketones as starting materials, the following procedure was typical:

*Ethyl methyl ketone oxime.* A solution of ethyl methyl ketone (2 g) in water was treated with hydroxylamine hydrochloride (4 g) and crystallized sodium acetate (8 g). The mixture was then warmed on a water bath for 30 minutes. It was then extracted with chloroform (2x100 ml) and the extract was washed with brine (40 ml) and dried. Removal of solvent and distillation gave ethyl methyl ketone oxime (2 g, 85%), bp 143-145°.

For aldehydes and ketones that are either sparingly soluble or insoluble in water, a representative procedure is described below.

*Acetophenone oxime.* A mixture of acetophenone (2 g), an equal weight of hydroxylamine hydrochloride, ethanol (20 ml) and pyridine (2 ml) is heated on a water bath for 1 h. The alcohol was removed by distillation. Water (20 ml) was added to the cooled residue and it was then cooled in an ice-bath to give the product. Crystallization from ethanol afforded needle-shaped crystals of acetophenone oxime (1.8 g, 80%) mp 57-58° (lit.\cite{62a} 59°). Similar procedures were followed to prepare oximes of isobutyl methyl ketone [mp 58° (lit.\cite{62a} 58°)], t-butyl methyl ketone [mp 76° (lit.\cite{62a} 78°)], 2-methoxy benzaldehyde [mp 90° (lit.\cite{62a} 92°)], 2,4-dimethoxybenzaldehyde [mp 104° (lit.\cite{62a} 106°)], 4-dimethylaminobenzaldehyde [mp 123° (lit.\cite{62a} 124°)], 3,4-methylenedioxybenzaldehyde [mp 107° (lit.\cite{62a} 110°)], citral (obtained as an oil), 4-nitrobenzaldehyde [mp 130-132°, (lit.\cite{62a} 133°)], mesityl oxide [mp 48° (lit.\cite{62a} 49°)], cinnamaldehyde [mp 136° (lit.\cite{64} 138.5°), 2-chloroacetophenone [mp 110° (lit.\cite{62a} 113°)], \(\alpha\)-tetralone oxime (reflux, 7 h) [mp 88°,
The following oximes were prepared using separate procedures:

**Syn-Benzaldehyde oxime**$^{62b}$: Benzaldehyde (0.5 ml) was added to a cooled solution of sodium hydroxide (4.2 g) in water (30 ml) in a conical flask and then hydroxylamine hydrochloride (0.5 g) was added. The mixture was vigourously stirred for 5 minutes. Further portions of benzaldehyde followed by hydroxylamine hydrochloride were added at 5 minute-intervals until both the reagents were completely added (total benzaldehyde used: 5.1 ml and hydroxylamine hydrochloride: 4.2 g). The reaction mixture was stirred till there was no almond-like odour of benzaldehyde. The mixture was then neutralized with acetic acid and then cooled in an ice-bath. It was then extracted with ether (2x30 ml). Careful removal of solvent from the dried combined ethereal extract gave syn-benzaldehyde oxime (2.8 g, 47%) as an oil.

**E-Benzilmonoxime.** A thin paste of benzil (10 g) with a little ethanol was treated with a concentrated aqueous solution of hydroxylamine hydrochloride (4.4 g). The mixture was cooled to $-5^\circ$ in an ice-bath and a 20% solution of NaOH (40 ml) was added with stirring and cooling (temperature of the mixture not to exceed $0^\circ$). After 90 minutes the mixture was diluted with water and filtered. The filtrate was then just acidified with glacial acetic acid and allowed to stand for 30 minutes when light-pink crystals of E-benzilmonoxime separated out. It was filtered out and crystallized from benzene to give the pure oxime (6 g, 56%), mp 138$^\circ$ (lit.$^{62a}$ 140$^\circ$). This oxime gave greenish colouration with alcoholic copper acetate solution.

**Z-Benzilmonoxime.** E-Benzilmonoxime (4 g) was boiled in benzene solution (40 ml) in the presence of animal charcoal for 30 minutes, hot-filtered to give solvated crystals of Z-benzil monoxime. It was then heated at 50-60$^\circ$ on water-bath and crystallized from carbon disulphide to give Z-benzilmonoxime (3 g, 75%) mp 110$^\circ$ (lit.$^{62a}$...
112°). It gave no colouration with alcoholic copper acetate solution indicating chelation of oxime hydroxy group with carbonyl group.

**Benzophenone oxime.** To a mixture of benzophenone (5 g), NH₂OH.HCl (3 g), rectified spirit (10 ml) and water (2 ml) was added sodium hydroxide (5.6 g) in portions with shaking and cooling in running tap water. The mixture was then refluxed for 5 minutes after the initial vigour of the reaction has subsided. The cooled reaction mixture was neutralized with HCl (15 ml conc. HCl in 100 ml water). The product was filtered, washed with cold water and crystallized from ethanol; yield of benzophenone oxime (5.1 g, 95%) mp 140° (lit.62a 142°).

**Cyclohexanone oxime.** To cyclohexanone (4 g) taken in a conical flask was added dropwise hydroxylamine generated from hydroxylamine hydrochloride (8 g) and 20% NaOH solution (20 ml) with due shaking and thorough cooling in an ice-bath. After the reaction is over, the crude product was filtered off and recrystallized from aqueous alcohol to give prism-shaped white crystals of cyclohexanone oxime (4.3 g, 94%) mp 89-90° (lit.62a 91°). Cyclopentanone oxime [mp 55° (lit.62a 57°)] was similarly prepared.

**syn-2-Furfuraldehyde oxime**. Furfuraldehyde (6.75 g) was added slowly to a cold mixture of sodium hydroxide (7 g in 7.5 ml water) and hydroxylamine hydrochloride (6 g in 15 ml water). After 1 h, the solution was filtered and cooled in a freezing mixture and a slight excess an ice-cold saturated aqueous solution of ammonium chloride was slowly added with stirring. The crystalline precipitate was washed with a little ice-cold water and air-dried to give the crude oxime. It was crystallized from benzene-light petroleum to afford syn-2-furfuraldehydeo xime (2 g, 26%) mp 75° (lit.66 75-76°).

**Representative procedure for the deoximation with pyridinium fluorochromate (PFC) adsorbed on wet alumina**

Alumina (20 g, neutral Brockman Grade 1) was activated at 100° for 4 h prior to use. It was then thoroughly mixed with a solution of PFC (4 g, 20 mmol) in water (6 ml) for 30 minutes at room temperature. The wet mixture thus prepared was then evaporated
to near dryness *in vacuo* and the orange powder so obtained was used as the reagent for deoximation. *syn*-Benzaldehyde oxime (1.2 g, 10 mmol) in dichloromethane (40 ml) was stirred with the reagent for 20 minutes (TLC-monitored). The solid material was then filtered, washed with ether (3x20 ml). The filtrate combined with washings was evaporated to give the crude product was chromatographed over silica gel (60-120 mesh) and distilled to give benzaldehyde (950 mg, 90%).

*Deoximations of some oximes with PFC on wet alumina support : 2-methoxybenzaldehyde oxime*

Activated alumina (8 g) was mixed with PFC (1.6 g, 8 mmol) in water (3 ml). The nearly vacuum-dried reagent so obtained was stirred with 2-methoxybenzaldehyde oxime (600 mg, 4 mmol) in dichloromethane (20 ml) for 10 minutes. Usual work-up gave 2-methoxy-benzaldehyde (470 mg, 88%), bp 232-234° (lit.\textsuperscript{62a} 236°). It was also found to be identical with an authentic sample of the same compound (co-TLC, superimposable IR).

*2,4-Dimethoxybenzaldehyde oxime*

2,4-dimethoxybenzaldehyde oxime (0.7 g, 3.86 mmol) in dichloromethane (20 ml) was stirred for 10 minutes with alumina (8 g) mixed with PFC (1.54 g, 7.74 mmol) in water (3 ml) and dried as indicated before. Work-up, as described above, gave 2,4-dimethoxybenzaldehyde (0.54 g, 84%), mp 65-67° (lit.\textsuperscript{62a} 69°). It was found to be identical with an authentic sample (co-TLC, superimposable IR).

*4-Dimethylaminobenzaldehyde oxime*

4-dimethylaminobenzaldehyde (1 g, 6.1 mmol) in dichloromethane (30 ml) was well-stirred for 10 minutes with PFC-wet alumina reagent prepared by adsorbing PFC (2.43 g, 12.2 mmol) in water (6 ml) on alumina (12 g) and processed as before. Usual work-up provided 4-dimethylaminobenzaldehyde (780 mg, 86%), mp 73° (lit.\textsuperscript{62a} 74°).

*2-Furfuraldehyde oxime*

The oxime (1.4 g, 12.6 mmol) in dichloromethane (50 ml) was stirred with the deoximating reagent prepared from PFC (5 g, 25 mmol) in water (7 ml) adsorbed on
alumina (25 g) and vacuum-dried as above, for 30 minutes. Work-up gave 2-furfural (1.16 g, 96%) bp 158° (lit. \textsuperscript{62a} 161°). It was found to be identical with an authentic sample (co-TLC, superimposable IR).

*Citral oxime*

The oxime (2 g, 13.1 mmol) in dichloromethane (50 ml) was stirred with PFC (5.3 g, 26.5 mmol) in water (8 ml) adsorbed on alumina (27 g) for 30 minutes to give citral (1.78 g, 98%) bp 231° [lit. \textsuperscript{65} 228°(d)].

*p-Nitrobenzaldehyde oxime*

The oxime (1.1 g, 6.6 mmol) in dichloromethane (40 ml) was stirred with PFC-on-wet alumina prepared from PFC (2.6 g, 13.2 mmol) in water (6.5 ml) adsorbed on alumina (13 g) and vacuum-dried as above for 8 h. Usual work-up afforded p-nitrobenzaldehyde (760 mg, 76%), mp 104° (lit. \textsuperscript{62a} 106°) identical in all respects (co-TLC, superimposable IR) with an authentic sample.

*Cinnamaldehyde oxime*

The oxime (900 mg, 6.1 mmol) was stirred in dichloromethane solution (40 ml) and PFC (2.43 g, 12.2 mmol) in water (6 ml) adsorbed on alumina (12 g) for 5 h. Work-up resulted in isolation of cinnamaldehyde as the sole product (730 mg, 90%) bp 252-254° (lit. \textsuperscript{65} 252°) identical with an authentic sample.

*Ethyl methyl ketone oxime*

PFC on wet alumina was prepared from PFC (7 g, 35 mmol) dissolved in water (11 ml) and absorbed on alumina (35 g) as above. It was stirred with the oxime (1.54 g, 17.7 mmol) in dichloromethane (40 ml) for 1 h. Usual work-up gave the parent ketone exclusively (1.25 g, 98%), bp 82° (lit. \textsuperscript{65} 80°).

*Isobutyl methyl ketone oxime*

PFC-on-wet alumina was prepared as above from PFC (3.5 g, 17.5 mmol) dissolved in water (5 ml) and alumina (18 g) as above. It was stirred with the oxime (1 g,
isobutylmethyl ketone (820 mg, 94%), bp 118° (lit.62a 117°).

**t-Butyl methyl ketone oxime**

The oxime (1.5 g, 13 mmol) dissolved dichloromethane (40 ml) was stirred with the deoximating reagent containing PFC (5.2 g, 26 mmol) dissolved in water (8 ml) and then adsorbed on alumina (26 g) for 4 h. Work-up yielded t-butyl methyl ketone (1.12 g, 86%), bp 104° (lit.62a 106°).

**Acetophenone oxime**

The oxime (1.4 g, 10.4 mmol) in dichloromethane (40 ml) was stirred with PFC (4.2 g, 21 mmol) in water (6 ml) adsorbed on alumina (21 g) for 6 h. Work-up gave acetophenone (1.15 g, 92%), bp 200° (lit.624 202°).

**Benzophenone oxime**

The oxime (1 g, 5.1 mmol) in dichloromethane (40 ml) was stirred for 7 h with PFC (2.1 g, 10 mmol) in water (4 ml) adsorbed on alumina (10 g) to give, after work-up, benzophenone (700 mg, 80%), mp 47° (lit.624 49°). It was identical in all respects with an authentic sample.

**Z-Benzilmonoxime**

The oxime (1.2 g, 5.33 mmol) in dichloromethane (50 ml) was stirred with PFC (2.14 g, 10.67 mmol) in water (4 ml) adsorbed on alumina (11 g) for 9 h to give benzil (870 mg, 78%), mp 93-95° (lit.65 95°) identical with an authentic sample.

**E-Benzil monoxime**

The oxime (600 mg, 2.67 mmol) in dichloromethane (30 ml) was stirred with PFC (1.1 g, 5.5 mmol) in water (3 ml) adsorbed on alumina (6 g) for 7 h to afford, after usual work-up, benzil (460 mg, 82%).
Cyclohexanone oxime

The oxime (1 g, 8.85 mmol) was dissolved in dichloromethane (40 ml) and was stirred with PFC (3.6 g, 18 mmol) in water (6 ml) adsorbed on alumina (18 g) for 10 h to give cyclohexanone (730 mg, 84%) bp 158° (lit.62 156°).

Oxidation of benzoin oxime with PFC on wet alumina support

Benzoin oxime (1.54 g, 6.78 mmol) in dichloromethane (40 ml) was stirred for 30 minutes with the deoximating reagent prepared from PFC (2.7 g, 13.5 mmol) in water (8 ml) adsorbed on alumina (14 g) and vacuum-dried as above. Usual work-up afforded benzil as the sole product (1.2 g, 85%) mp 94° (lit.65 95°).

Cyclopentanone oxime

The oxime (900 mg, 9 mmol) was dissolved in dichloromethane (20 ml) and allowed to react with PFC-on-wet alumina reagent prepared, as above, from PFC (3.6 g, 18 mmol) in water (6 ml) adsorbed on alumina (18 g) for 10 h. Usual work-up gave the ketone (610 mg, 80%) bp 133° (lit.62 131°) identical in all respects (co-TLC, superimposable IR) with an authentic sample of cyclopentanone.

Attempted deoximation of camphor oxime

The oxime (1.1 g, 6.6 mmol) was dissolved in dichloromethane (40 ml) and stirred with the deoximating reagent prepared from PFC (2.65 g, 13.25 mmol) in water (4 ml) adsorbed on alumina (13 g) for 36 h. Usual work-up gave back the starting material only.

Attempted deoximation of 1-tetralone oxime

1-tetralone oxime (600 mg, 3.7 mmol) in a solution of dichloromethane (20 ml) was stirred for 36 h with the deoximating reagent prepared from an aqueous solution of PFC [1.5 g (7.5 mmol) in water (4 ml)] adsorbed on alumina (8 g) to give back, after usual work-up, the unreacted oxime only.
**Attempted deoximation of Hagemann's ester oxime**

The oxime (800 mg, 4.4 mmol) in dichloromethane solution (20 ml) was stirred for 36 h with the deoximating reagent [PFC (1.76 g, 8.8 mmol) in water (4 ml) adsorbed on alumina (9 g)]. The starting oxime was recovered only after usual work-up.

**Typical procedure for the oxidative cleavage of aryl aldoximes under homogeneous conditions:**

A solution of pyridinium fluorochromate (1.2 g, 6 mmol) in acetone (15 ml) cooled to 0°C was added dropwise to a solution of syn-benzaldehyde oxime (320 mg, 3 mmol) in acetone (5 ml) with stirring. The reaction mixture was then stirred at room temperature for 20 minutes and then acetone was removed under water suction. The crude mass was repeatedly extracted with ether (5x20 ml) and the combined ethereal extract was washed with 5% sodium sulphite solution (10 ml), 1 N hydrochloric acid (10 ml), water (10 ml) and then dried over anhydrous sodium sulphate. The crude product showed, in addition to the TLC spot identical with that of benzaldehyde, a spot corresponding to benzoic acid. Removal of solvent, chromatography over silica gel (60-120 mesh, BDH) and distillation under reduced pressure afforded benzaldehyde (225 mg, 80%).

**Deoximation of 2-methoxybenzaldehyde oxime with PFC in acetone solution**

A solution of PFC (1.6 g, 8 mmol) in acetone (20 ml) cooled to 0-5°C was added dropwise to a solution of 2-methoxybenzaldehyde oxime (600 mg, 4 mmol) in acetone (7 ml) with stirring. The reaction mixture was then stirred at room temperature for 10 minutes. Work-up, as described above, afforded 2-methoxybenzaldehyde (410 mg, 76%) and some 2-methoxybenzoic acid (40 mg), mp 100° (lit.62a 101°).

**Cleavage of 2,4-dimethoxybenzaldehyde oxime**

A solution of PFC (1.54 g, 7.5 mmol) in acetone (7 ml) was added dropwise to a solution of 2,4-dimethoxybenzaldehyde oxime (700 mg, 3.86 mmol) in acetone (10 ml) at 0-5°C and then the mixture was stirred at room temperature for 15 minutes. Usual work-up gave 2,4-dimethoxybenzaldehyde (450 mg, 70%) along with 2,4-dimethoxybenzoic acid (50 mg) mp 108° (lit.64 108-109°).
Cleavage of 4-dimethylaminobenzaldehyde oxime

To a solution of 4-dimethylaminobenzaldehyde oxime (600 mg, 3.6 mmol) in acetone (7 ml) was added dropwise a solution of PFC (1.44 g, 7.2 mmol) in acetone (17 ml) at 0° and then stirred at room temperature for 15 minutes. Usual work-up afforded 4-dimethylaminobenzaldehyde (380 mg, 70%) and some 4-dimethylaminobenzoic acid (80 mg), mp 241° (lit.64 242.5-243.5°).

Cleavage of 2-furfural oxime

The oxime (500 mg, 4.5 mmol) in acetone (15 ml) was added dropwise to a solution of PFC (1.8 g, 9 mmol) in acetone (15 ml) at 0° with stirring. The reaction was then stirred at room temperature for 45 minutes. Work-up yielded 2-furfural (350 mg, 82%) and a minor amount of furan-2-carboxylic acid (60 mg), mp 130-131° (lit.65 133°).

Oxidative cleavage of citral oxime

A solution of citral oxime (700 mg, 4.2 mmol) in acetone (20 ml) was added at 0-5° to a solution of PFC (1.68 g, 8.4 mmol) in acetone (20 ml) and then stirred for 45 minutes at room temperature. Usual work-up yielded citral (500 mg, 78%).
Typical procedure for oxidative cleavage of oximes with PFC in combination with 30% \( \text{H}_2\text{O}_2 \):

To a well-stirred solution of PFC (5.97 g, 30 mmol) and benzophenone oxime (2.95 g, 15 mmol) in acetone (30 ml) a 30% \( \text{H}_2\text{O}_2 \) solution (7.5 ml) was added dropwise maintaining the temperature at 0-10°. The reaction mixture was stirred for 5 h (TLC-monitored) and then acetone was slowly removed under reduced pressure. The residue was extracted with ether (3x25 ml) after addition of water (10 ml). The combined ethereal extract was washed successively with 5% sodium sulphite solution (10 ml), 1 N HCl (10 ml) and water (15 ml). The washed and dried extract gave crude product after removal of solvent. Chromatography over silica gel (60-120 mesh, 20 g) afforded benzophenone (2.67 g, 98%) mp 46-47° (lit.\textsuperscript{62a} 49°).

Cleavage of some oximes with PFC and 30% \( \text{H}_2\text{O}_2 \): syn-Benzaldehyde oxime

To a well-stirred solution of syn-benzaldehyde oxime (1.6 g, 13.2 mmol) and PFC (5.3 g, 26.5 mmol) in acetone (50 ml) was added 30% \( \text{H}_2\text{O}_2 \) solution (7 ml) at 0° and the mixture was stirred at room temperature for 20 minutes. Usual work-up and chromatographic separation gave benzaldehyde (1.04 g, 74%) and some benzoic acid (160 mg, 10%), mp 121° (lit.\textsuperscript{62*} 121°).

2-Methoxybenzaldehyde oxime

To a solution of 2-methoxybenzaldehyde oxime (1.2 g, 7.94 mmol) and PFC (3.2 g, 16 mmol) in acetone (50 ml) was added 30% \( \text{H}_2\text{O}_2 \) solution (4 ml) carefully at 0 to 10° and then stirred for 10 minutes at room temperature. Usual work-up afforded 2-methoxybenzaldehyde (690 g, 64%) and the corresponding acid (300 mg, 25%).

2,4-dimethoxybenzaldehyde oxime

To a solution of the oxime (1.2 g, 6.63 mmol) in acetone (30 ml) and PFC (2.65 g, 13.25 mmol) in acetone (20 ml) added 30% \( \text{H}_2\text{O}_2 \) solution (6.5 ml) at 0 to 5°. The reaction mixture was then stirred for 10 minutes at room temperature. Usual work-up and chromatographic separation led to the isolation of the parent aldehyde (600 mg, 54%) mp
65-67° (lit.\textsuperscript{62a} 69°) and substantial amount of 2,4-dimethoxybenzoic acid (360 mg, 30%) mp 110° (lit.\textsuperscript{64} 108-109°).

4-Dimethylaminobenzaldehyde oxime

To a solution of the oxime (1 g, 6.1 mmol) in acetone (20 ml) and PFC (2.44 g, 12.2 mmol) in acetone (20 ml) was added a 30% H\textsubscript{2}O\textsubscript{2} solution (3 ml) carefully at 0-5°. The blue-violet mixture was then stirred for another 10 minutes at room temperature. Usual work-up and chromatographic purification afforded 4-dimethylaminobenzaldehyde (620 mg, 68%) mp 72° (lit.\textsuperscript{62a} 74°) and the corresponding acid (280 mg, 28%), mp 244° (lit.\textsuperscript{64} 242.5-243.5°).

Citral oxime

To a solution of the oxime (1 g, 5.98 mmol) in acetone (20 ml) was added with cooling (0-5°), a solution of PFC (2.4 g, 12 mmol) in acetone (20 ml). To this reaction mixture was then added 30% H\textsubscript{2}O\textsubscript{2} solution (3 ml) and the mixture was stirred at room temperature for 15 minutes. Usual work-up and chromatographic purification gave citral (710 mg, 78%).

Isobutyl methyl ketone oxime

To a mixture of isobutyl methyl ketone oxime (1 g, 8.7 mmol) and PFC (3.5 g, 17.5 mmol) in acetone (50 ml) was added carefully a solution of 30% H\textsubscript{2}O\textsubscript{2} (4.5 ml) at 0-5°. The mixture was stirred for 20 minutes at room temperature. Work-up and filtration through a column of silica gel (20 g) gave isobutyl methyl ketone (850 mg, 98%) only.

t-Butyl methyl ketone oxime

To a solution of the oxime (800 mg, 6.95 mmol) in acetone solution (20 ml) was added PFC (2.8 g, 14 mmol) in acetone (20 ml) and then 30% H\textsubscript{2}O\textsubscript{2} solution (3.5 ml) dropwise at 0-5°. The reaction mixture was then stirred for 1.5 h at room temperature. Usual work-up and chromatographic purification gave t-butyl methyl ketone (675 mg, 97%).
4-Nitrobenzaldehyde oxime

To a well-stirred solution of the oxime (900 mg, 5.42 mmol) in acetone (20 ml) was added, with stirring, a solution of PFC (2.17 g, 10.8 mmol) in acetone (20 ml) and then 30% H₂O₂ solution (2.8 ml) was added carefully. The mixture was stirred at room temperature for 5 h. Usual work-up yielded, after chromatographic purification over silica gel, 4-nitrobenzaldehyde (730 mg, 89%) mp 105° (lit.62a 106°).

3,4-Methylenedioxybenzaldehyde oxime

A solution of the oxime (1.6 g, 9.7 mmol) in acetone (20 ml) and PFC (3.9 g, 9.75 mmol) in acetone (20 ml) was stirred with 30% H₂O₂ solution (5 ml) for 15 minutes at room temperature. The reaction mixture was then worked up as usual to yield a crude product which gave, after chromatographic purification, 3,4-methylenedioxybenzaldehyde (1020 mg, 70%), bp 261-263° (lit.65 263°). A small amount of 3,4-methylenedioxy-benzoic acid (170 mg, 11%) mp 227° (lit.65 229°) was also obtained as a by-product.

Mesityl oxide oxime

To a solution of the oxime (1.1 g, 8 mmol) in acetone (20 ml) was added a solution of PFC (3.2 g, 16 mmol) in acetone (20 ml) and then 30% H₂O₂ solution (4 ml) at 0-5°. The mixture was stirred at room temperature for 4 h and worked up as before. The crude product so obtained showed one TLC spot only and after chromatographic purification gave mesityl oxide (900 mg, 92%) bp 128° (lit.65 130°).

Acetophenone oxime

To a solution of acetophenone oxime (1.7 g, 12.6 mmol) in acetone (20 ml) was added PFC (5 g, 25 mmol) in acetone (25 ml) and then 30% H₂O₂ (6 ml) dropwise at 0-5°. The mixture was stirred at room temperature for 4 h to give, after usual work-up, acetophenone (1.39 g, 92%) bp 200° (lit.65 202°).
2-Chloroacetophenone oxime

To a solution of the oxime (1.7 g, 10 mmol) in acetone (20 ml) was added PFC (4 g, 20 mmol) in acetone (20 ml) and then 30% \( \text{H}_2\text{O}_2 \) (5 ml) dropwise at 0-5°. The reaction mixture was then stirred for 6 h and then worked up as before to yield 2-chloroacetophenone (1.46 g, 94%) bp 231° (lit.62a 229°).

E-Cinnamaldehyde oxime

To a solution of the oxime (1.5 g, 10.2 mmol) in acetone (20 ml) was added PFC (4 g, 20 mmol) in acetone (20 ml) and then 30% \( \text{H}_2\text{O}_2 \) solution (5 ml) dropwise. The mixture was stirred at room temperature for 3 h and then worked up, as before, to yield cinnamaldehyde (1.2 g, 88%), bp 250° [lit.62a 252°(d)].

1-Indanone oxime

To a solution of 1-indanone oxime (1.5 g, 10.2 mol) in acetone (10 ml) was added, with stirring, PFC (4.1 g, 20.5 mmol) in acetone (20 ml) and then 30% \( \text{H}_2\text{O}_2 \) solution (5 ml) at 0-5°. The reaction mixture was stirred for 6.5 h and then worked up as before to afford 1-indanone (1.2 g, 90%) mp 40° (lit.65 42°).

Z-Benzilmonoxime

To a mixture of the solution of the oxime (1 g, 4.44 mmol) in acetone (15 ml) and PFC (1.8 g, 9 mmol) in acetone (15 ml) was added 30% \( \text{H}_2\text{O}_2 \) solution (2 ml) dropwise and then the mixture was stirred for 6 h at room temperature. Usual work-up yielded benzil (840 mg, 90%) mp 94° (lit.65 95°).

E-Benzilmonoxime

To a mixture of the solution of the oxime (600 mg, 2.67 mmol) in acetone (10 ml) and PFC (1.1 g, 5.5 mmol) in acetone (10 ml) was added 30% \( \text{H}_2\text{O}_2 \) solution (3 ml) dropwise and the mixture was stirred for 4 h. Usual work-up gave benzil (520 mg, 92%), mp 95°.
Cyclohexanone oxime

To a mixture of the oxime (2 g, 17.7 mmol) in acetone (20 ml) and PFC (7 g, 35 mmol) in acetone (25 ml) was added 30% H₂O₂ solution (9 ml) in three portions and the mixture was stirred at room temperature for 4 h. Usual work-up gave cyclohexanone (1.7 g, 98%) bp 156° (lit.62a 156°).

Cyclopentanone oxime

To a mixture of cyclopentanone oxime (1 g, 10.1 mmol) in acetone (20 ml) and PFC (4 g, 20 mmol) in acetone (15 ml) was added, with stirring, 30% H₂O₂ solution (5 ml) and the mixture was stirred for 2.5 h. Usual work-up gave a crude product which upon distillation gave cyclopentanone (810 mg, 96%) bp 130° (lit.62a 131°).

1-Tetralone oxime

a) To a mixture of 1-tetralone oxime (800 mg, 5 mmol) in acetone (10 ml) and PFC (2 g, 10 mmol) in acetone (10 ml) was added 30% H₂O₂ solution (2.5 ml) and the mixture was stirred for 24 h. Work-up, as before, yielded 1-tetralone (570 mg, 78%), bp 125°/10 mmHg (lit.62a 129°/12 mmHg).

b) To a solution of 1-tetralone oxime (1 g, 6.2 mmol) in acetone (15 ml) and PFC (4.96 g, 24.8 mmol) in acetone (25 ml) was added 30% H₂O₂ (6.2 ml) in three portions. The mixture was stirred for 18 h and then worked up to yield 1-tetralone (830 mg, 92%).

Camphor oxime

a) To a mixture of camphor oxime (500 mg, 3 mmol) in acetone (10 ml) and PFC (1.2 g, 6 mmol) in acetone (10 ml) was added 30% H₂O₂ solution (1.5 ml) and the mixture was stirred at room temperature for 30 h. Work-up, as before, afforded camphor (400 mg, 88%) mp 177° (lit.65 179°).

b) To a mixture of the oxime (700 mg, 4.2 mmol) in acetone (15 ml) and PFC (3.4 g, 17 mmol) in acetone (20 ml) was added 30% H₂O₂ (4 ml) and the mixture was stirred for 20 h to give, after usual work-up, camphor (610 g, 96%).
Hagemann's ester oxime (4-carbethoxy-3-methyl-2-cyclohexen-1-one oxime)

To a mixture of the oxime (900 mg, 4.57 mmol) in acetone (10 ml) was added PFC (1.83 g, 9.15 mmol) in acetone (15 ml) and then 30% H₂O₂ (2.3 ml). The mixture was stirred for 8 h and worked up as before to yield Hagemann's ester (720 mg, 86%), distilling at 100° / 0.2 mm of Hg.

Deprotection of some aldoximes under controlled conditions: A typical procedure

To a well-stirred mixture of syn-benzaldehyde oxime (0.48 g, 4 mmol) and PFC (1.6 g, 8 mmol) in acetone (20 ml) in a two-necked flask was added 30% H₂O₂ solution (2 ml) dropwise over a period of 10 minutes maintaining the temperature at -10°. After the addition is complete, the mixture was stirred at -10° for another 10 minutes. Removal of acetone in vacuo, usual work-up and chromatographic purification gave benzaldehyde (0.35 g, 83%).

Deprotection of some easily oxidizable aldoximes under controlled conditions:

a) 2-Methoxybenzaldehyde oxime

To a well-stirred solution of the oxime (500 mg, 3.3 mmol) and PFC (1.3 g, 6.5 mmol) in acetone (20 ml) kept at -10° was added 30% H₂O₂ solution (1.6 ml) dropwise for 5 minutes. The mixture was stirred for another 5 minutes at -10° and then worked up as before to give 2-methoxybenzaldehyde (390 mg, 86%) and some 2-methoxybenzoic acid (30 mg, 6%), mp 101° (lit.⁶² 101°).

b) 2,4-Dimethoxybenzaldehyde oxime

To a well-stirred solution of the oxime (800 mg, 4.4 mmol) and PFC (1.7 g, 8.5 mmol) at -10° was added dropwise a 30% H₂O₂ solution (2 ml) at -10° over a period of 5 minutes. Stirring for another 10 minutes at -10° and usual work-up afforded 2,4-dimethoxybenzaldehyde (650 mg, 89%) and a small amount of 2,4-dimethoxybenzoic acid (65 mg, 8%), mp 107° (lit.⁶² 108-109°).
c) 4-dimethylaminobenzaldehyde oxime

To a mixture of the oxime (720 mg, 4.39 mmol) and PFC (1.76 g, 8.8 mmol) in acetone (20 ml) at $-10^\circ$ was added dropwise 30% $\text{H}_2\text{O}_2$ solution (2 ml) at $-10^\circ$ over a period of 5 minutes and then the reaction mixture was stirred at $-10^\circ$ for another 5 minutes. Usual work-up afforded 4-dimethylaminobenzaldehyde (590 mg, 90%) and some 4-dimethylaminobenzoic acid (40 mg, 6%) mp 240° (lit.$^64$ 242.5-243.5°).

d) 3,4-methylenedioxybenzaldehyde oxime

To a well-stirred solution of the oxime (860 mg, 5.2 mmol) and PFC (2 g, 10 mmol) in acetone (25 ml) cooled to $-10^\circ$ was added 30% $\text{H}_2\text{O}_2$ solution (2.6 ml) dropwise over a period of 5 minutes. The mixture was then stirred for 10 minutes at $-10^\circ$ and worked up as before to give the parent aldehyde (630 mg, 80%) and some corresponding acid (40 mg, 5%), mp 230° (lit.$^65$ 229°).

e) Deoximation of citral oxime

To a well-stirred solution of citral oxime (740 mg, 4.43 mmol) and PFC (1.76 g, 8.8 mmol) in acetone (25 ml) at $-10^\circ$ was added 30% $\text{H}_2\text{O}_2$ solution (2.2 ml) over a period of 10 minutes at $-10^\circ$. The mixture was further stirred for 5 minutes at $-10^\circ$. Usual work-up gave citral (640 mg, 95%).

Preparation of acetophenone-O-methyl oxime:

Acetophenone oxime (1 g, 7.4 mmol) dissolved in hot alcohol (10 ml) was treated with sodium ethoxide (0.4 g of sodium in 6 ml of alcohol) and methyl iodide (1.42 g, 10 mmol) was added. The solution was refluxed for 1 h and then kept overnight. The alcohol was evaporated and an excess of water was added. Extraction with ether (3x20 ml), drying and removal of solvent gave a thick oil (0.9 g). It shows no IR band in the hydroxy region.
**Attempted deoximation of acetophenone-O-methyl oxime with PFC on wet alumina support**

O-Methyl ether of the oxime (500 mg, 3.36 mol) was dissolved in dichloromethane (20 ml) and stirred for 36 h with the deoximating reagent prepared from PFC (1.4 g, 7 mmol) dissolved in water (4 ml) and adsorbed on alumina (7 g). Usual work-up gave back the starting material only.

**Attempted deoximation of acetophenone-O-methyl oxime with PFC and 30% H\textsubscript{2}O\textsubscript{2}**

To a solution of O-methyl ether of acetophenone oxime (400 mg, 2.68 mmol) in acetone (20 ml) was added PFC (1.1 g, 5.4 mmol) in acetone (10 ml) and 30% H\textsubscript{2}O\textsubscript{2} solution (1.5 ml). The mixture was stirred for 20 h at room temperature. Usual work-up led to the recovery of the starting material only.

**Attempted deoximation of acetophenone oxime-O-acetate with PFC on wet alumina support**

Acetophenone oxime-O-acetate (650 mg, 3.67 mmol) was dissolved in dichloromethane (20 ml) and stirred for 20 h with the deoximating reagent prepared from PFC (1.47 g, 7.35 mmol) dissolved in water (4 ml) and then adsorbed on alumina (8 g) and vacuum-dried, as before. Usual work-up gave back the starting material only.
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