INTRODUCTION
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Oxidation is an essential operation in organic synthesis and several reagents have been developed for a wide variety of transformations (1-3). Hexavalent chromium compounds have been widely used as oxidizing agents reacting with diverse kinds of organic substrates. The mechanism of oxidation varies with the nature of the chromium(VI) species and the solvent used. A large number of novel chromium(VI) oxidizing agents have been introduced, mostly in response to the needs of mildness and selectivity. Since the process of oxidation is of great value as a fundamental process in a wide scope of chemical conversions, there has been considerable interest in the development of newer chromium(VI) reagents for oxidation reactions. There exists a need for new methods, especially for complex or highly sensitive substances where great selectivity and effectiveness, coupled with mildness of conditions are prerequisites for success. New procedures are emerging, involving “non-aqueous” chromium(VI) reagents and the general idea that anhydrous conditions are more conducive to mild oxidation.

The earliest known chromium(VI) oxidants were chromium trioxide and chromyl chloride. Chromyl chloride has generally been used in carbon tetrachloride or carbon disulfide media. Chromium trioxide has been used in various kinds of reaction media such as water, acetic acid, sulfuric acid, acetic anhydride, acetone, t-butyl alcohol and pyridine.

In recent years, a large number of novel chromium(VI) oxidizing agents have been introduced, mostly in response to the needs of mildness and selectivity. The “Jones
"Jones reagent" was introduced for the oxidation of organic compounds (4-6). This reagent was a solution of chromium(VI) oxide in concentrated sulfuric acid, which was added drop wise to the substrate dissolved in acetone. The usefulness of the "Jones reagent" has been established.

Several facile oxidations of secondary alcohols were achieved with chromic acid in a two-phase system of ether and water. This method proved particularly suitable for the synthesis of ketones, which were susceptible to epimerization under oxidizing conditions (7).

In order to protect acid-sensitive functional groups during the oxidation of alcohols with Cr(VI) oxide, polar aprotic solvents have been used. A solution of Cr(VI) oxide in dimethylformamide, containing a trace of concentrated sulfuric acid, was able to oxidize alcohols containing acid-sensitive protecting groups. The presence of catalytic amounts of sulfuric acid was essential, accompanied by low temperatures and an inert nitrogen atmosphere (8). When a solution of Cr(VI) oxide was added to an equal volume of the substrate (alcohol), dissolved in hexamethyl phosphoric triamide (HMPT), simple axial and equatorial hydroxyl functions were oxidized, the latter at a much faster rate. Under the same experimental conditions, Cr(VI) oxide in HMPT was found to oxidize allylic hydroxyl functions in preference to other alcoholic groups (9). A series of primary and secondary alcohols were oxidized in 80-90% yields by a solution of sodium dichromate dihydrate, in concentrated sulfuric acid, in dimethyl sulfoxide (DMSO) at 70°C. In these oxidations, DMSO acted as a solvent and not as an oxidant, as shown by the negligible oxidation of the substrates in the absence of dichromate (10).
One of the earliest and most widely employed chromium(VI) oxidants has been the "Collins reagent", dipyridinium-Cr(VI) oxide in dichloromethane (11). Collins reagent has been extensively used for the oxidation of primary and secondary alcohols (12-20).

The technique of using reagents intercalated in, or adsorbed on, a solid support has also been exploited in oxidations with chromium(VI) oxidizing agents. The solid supports used have included graphite, silica, alumina, silica gel and celite. As in the case of many Cr(VI) reagents, attempts were made to achieve mild reaction conditions, better selectivity and convenient isolation of the oxidation products. On heating with graphite under reduced pressure, chromium(VI) oxide was claimed to be uniformly intercalated, and the resulting substance was found to oxidize primary alcohols to aldehydes in high yields (21). Later work showed that the oxidizing agent was a surface deposit of chromium(VI) oxide on graphite (22-23). Collins reagent (11), adsorbed on celite, has been used to oxidize allylic alcohols to the corresponding aldehydes (24).

Chromium(VI) oxide, in conjunction with 3,5-dimethyl pyrazole (25), has been used to oxidize primary and secondary alcohols. This reagent was presumed to form a cyclic chromate ester that generated the corresponding carbonyl compound through intramolecular elimination. Despite the high yields of some simple aldehydes and ketones from the corresponding alcohols and near quantitative oxidation of geraniol (25), this reagent did not give satisfactory yields in a number of cases (16, 26).

For oxidation purposes, the most widely used Cr(VI) complex with pyridine has been pyridinium chlorochromate (PCC), popularly known as "Corey's reagent" (27).
Its principal advantage was that this reagent was not air- or moisture-sensitive, and oxidation with it did not involve handling a large volume of solvent. Studies on the kinetics of oxidation of primary alcohols by PCC have provided important information on the mechanism of the process (28). Involvement of protonated chromium species in the rate-determining step was indicated by the catalysis of the reaction by acid, the acid-catalyzed reaction being first order. PCC did not polymerize acrylonitrile, and a hydrogen transfer hypothesis was thus not tenable. A substantial kinetic isotope effect, $k_H / k_D = 5.71$, at 303K suggested a hydride transfer in the rate-determining step. The transfer could occur directly between the alcohol and the protonated species or intramolecularly after the initial formation of a chromate ester (28). A few representative examples of oxidation of primary and secondary alcohols by PCC have been given in Table 1.
Table 1: Oxidation of Primary and Secondary Alcohols by PCC, in dichloromethane at 25°C (ref 27).

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>Product</th>
<th>Yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Heptanol</td>
<td>Heptanal</td>
<td>78</td>
</tr>
<tr>
<td>1-Decanol</td>
<td>Decanal</td>
<td>92</td>
</tr>
<tr>
<td>1,6-Hexanediol</td>
<td>Hexanediol</td>
<td>68</td>
</tr>
<tr>
<td>Oct-2-yn-1-ol</td>
<td>Oct-2-yn-al</td>
<td>84</td>
</tr>
<tr>
<td>Citronellol</td>
<td>Citronellal</td>
<td>82</td>
</tr>
<tr>
<td>Benzhydrol</td>
<td>Benzophenone</td>
<td>100</td>
</tr>
<tr>
<td>4-t-Butylcyclohexanol</td>
<td>4-t-Butylcyclohexanone</td>
<td>97</td>
</tr>
<tr>
<td>Presqualene alcohol</td>
<td>Presqualene aldehyde</td>
<td>78</td>
</tr>
</tbody>
</table>

Pyridine oxodiperoxychromium(VI), C$_5$H$_5$N:CrO$_5$, a complex of chromium pentoxide with pyridine, has been used for the oxidation of primary and secondary alcohols. This reagent was prepared by the addition of aqueous H$_2$O$_2$ to an aqueous solution of chromium(VI) oxide containing pyridine, maintained at low temperature (29).

Chromic acid supported on an ion-exchange resin has been used to oxidize primary and secondary alcohols (30). This polymer-supported reagent was prepared by the addition of the chloride form of the resin to an aqueous solution of chromium(VI) oxide under stirring. Chromyl chloride, adsorbed on silica-alumina, was found to be an
effective oxidizing agent for primary and secondary alcohols, under neutral non-
aqueous conditions. This reagent was prepared by the addition of chromyl chloride, in
dichloromethane, to a slurry of the adsorbent, also taken in dichloromethane (31). The
instantaneous oxidation of primary and secondary alcohols, in good yields, were
obtained using chromic acid adsorbed on silica gel (32). This reagent was prepared by
adding a weighed amount of silica gel to a solution of chromium(VI) oxide in water
(32). Pyridinium chlorochromate (PCC), supported on a polymer, was found to be an
efficient system for the oxidation of alcohols to the corresponding carbonyl compounds
(33). This reagent, poly[vinyl(pyridinium chlorochromate)], (PVPCC), was prepared by
the addition of chromium(VI) oxide and concentrated hydrochloric acid to polyvinyl
pyridine suspended in water (33). Pyridinium chlorochromate, adsorbed on alumina,
has been claimed to be a better oxidizing agent than PCC taken in dichloromethane
suspension (34). Thus, carveol was efficiently oxidized to carvone, and no cationic
cyclization was observed during the conversion of citronellol to citronellal (34).

The difficulties in handling Collins reagent and the problem arising out of the
acidic nature of Corey’s reagent were overcome by the use of pyridinium dichromate,
(PyH)2Cr2O7 (PDC), which was recognized as a mild and selective oxidizing agent (35).
This reagent was soluble in a number of solvents, though an aprotic medium was
necessary for getting satisfactory results. PDC was generally used either in solution in
dimethylformamide or as a suspension in dichloromethane. Anhydrous conditions were,
used during oxidation with PDC, and when the oxidation was performed in
dimethylformamide, the carbonyl compounds were isolated by ether extraction after
pouring the reaction mixture in water. PDC showed remarkable selectivity as an
oxidizing agent. When dissolved in dimethylformamide, it clearly oxidized allylic alcohols to the corresponding α,β-unsaturated aldehydes in excellent yields. PDC in dichloromethane oxidized primary and secondary alcohols efficiently. The aldehydes obtained as products from primary alcohols did not undergo further oxidation (35).

In the presence of a mixture of ether and dichloromethane, chromium(VI) oxide was used to oxidize several secondary alcohols, in the presence of celite. The best results were obtained by the addition of solid chromium(VI) oxide to an ice-cold solution of the substrate (alcohol) in ether-dichloromethane as the solvent mixture, with celite as a suspension (36).

There have been several reports on the oxidation of primary and secondary alcohols by various chromium(VI) oxidants under phase-transfer catalysis (37-41). Some of the phase-transfer catalysts employed have included Adogen 464 (a commercially available mixture of methyltrialkyl-ammonium chloride, ref.37), tetrabutylammonium bisulfate (38,39), and tetra-n-butylammonium chloride (40,41). Allylic and benzylic alcohols were efficiently oxidized to the corresponding aldehydes with bis-tetrabutylammonium dichromate (TBADC) in refluxing dichloromethane (42).

The 2,2-bipyridine complex of chlorochromic acid was a useful oxidizing agent which had resulted in simplified procedures for the purification of the resulting carbonyl compounds. The 2,2-bipyridinium chlorochromate and the 2,2-bipyridine-chromium trioxide complex have both proved to be specially useful in oxidations of compounds with acid-sensitive protecting groups, due to the internal buffering of the 2,2-bipyridyl system. These results indicated that synthetically useful changes in the
properties and reactivity of Cr(VI) reagents could be brought about by varying the amine ligand associated with chromium trioxides (43).

The pyridinium chlorochromate / \( \text{H}_2\text{O}_2 \) system has been used as an oxidative reagent for the conversion of oximes to parent carbonyl compounds in reasonably good yields (44). Pyridinium chlorochromate in dichloromethane containing 2% pyridine at 2-3°C was reported to effect the high-yield selective oxidation of the allylic hydroxyl function of a number of steroidal alcohols (45).

The oxidation of complex allylic and benzylic alcohols to the corresponding carbonyl compounds was achieved using a mild selective reagent, 4-(dimethyl amino) pyridinium chlorochromate. Secondary alcohols proved to be more reactive towards this reagent than primary alcohols. The ready preparation of this oxidizing agent, its selectivity, and the ease of using this reagent indicated its effectiveness for the oxidation of complexed allylic and benzylic alcohols (46).

The pyridinium chlorochromate-iodine system was found to be an efficient method for the conversion of enol silyl ethers to \( \alpha \)-iodoketones in excellent yields (47). A highly selective oxidant, bis[benzyltriethyl ammonium] dichromate, was prepared and used for the oxidation of active alcohols to the corresponding carbonyl compounds, and of mercaptans to disulfides in hexamethyl phosphoric triamide (HMPT) as solvent; the yields reported were almost quantitative (48).

Since the process of oxidation in organic chemistry is of great value as a fundamental process in a wide scope of chemical conversions, there has been
considerable interest in the development of newer chromium(VI) reagents for oxidation reactions. Since the introduction of pyridinium chlorochromate (27), and its extensive use as a versatile oxidant in organic synthesis (49), several new oxidizing agents have been developed, varying the amine ligand associated with the chlorochromate anion.

A new Cr(VI) reagent, pyridinium fluorochromate (PFC), was found to have certain advantages over similar oxidizing agents, in terms of the amounts of oxidant and solvent required, shorter reaction times, and high yields. In dichloromethane as solvent, PFC was found to oxidize primary and secondary alcohols to the corresponding aldehydes or ketones, respectively, and was also found to oxidize benzoin to benzil, as also anthracene and phenanthrene to their corresponding quinones (50).

At room temperature, tetrabutyl ammonium chlorochromate (TBACC), in chloroform, was used as a selective reagent for the oxidation of alcohols such as geraniol, which was converted to geranial in excellent yields (51).

Two new chlorochromate complexes were prepared and used as mild oxidizing agents. These were: (a) 1,8-naphthyridinium chlorochromate (C₈H₆N₂HCrO₃Cl); and (b) pyrazinium chlorochromate (C₄H₁₂N₂HCrO₃Cl). These two reagents, taken in dichloromethane as solvent, were used to oxidize benzylic and cyclic alcohols to corresponding carbonyl products in good yields (52).

Bis-(trimethylsilyl) peroxide (BTSP), in the presence of Cr(VI), has been used to oxidize alcohols to the corresponding ketones. A solution of Me₃SiOOSiMe₃ (BTSP) in dichloromethane, in the presence of pyridinium dichromate, was used to oxidize borneol
to camphor, as also for the conversion of cyclic alcohols to cyclic ketones in good yields (53, 54).

Pyridinium chlorochromate (PCC), in conjunction with 3,5-dimethylpyrazole (DMP), in dichloromethane as solvent, was found to be a convenient and useful reagent for the rapid and selective oxidation of steroidal allylic alcohols. The selectivity of this reagent was such that primary and secondary alcohols did not undergo significant oxidation, relative to allylic alcohols (55, 56).

Among many chromium(VI) reagents examined, pyridinium fluorochromate (PFC) was as reactive as pyridinium chlorochromate (PCC), and oxidation took place at 25°C (57). The reaction with benzyl-trimethylammonium chlorochromate (BTMACC) proceeded very slowly at 25°C, and the completion of the reaction in 1,2-dichloroethane required heating at 80°C (57). However, BTMACC was able to convert alcohols to the corresponding carbonyl compounds in very good yields. Tetrabutylammonium chlorochromate (TBACC) was also able to carry out these oxidation reactions, though with yields which were much less than the yields obtained by oxidation with BTMACC (57). Other reagents which were prepared had included tetramethylammonium fluorochromate (TMAFC), tetramethylammonium chlorochromate (TMACC) and tetrabutylammonium fluorochromate (TBAFC), but all these reagents were found to be inert for the oxidation of alcohols (57).

A useful contribution to organic synthesis was the preparation of tetrakis (pyridine) silver dichromate, $\text{Py}_4\text{Ag}_2\text{Cr}_2\text{O}_7$, which was used for the oxidation of benzylic and
allylic alcohols in refluxing benzene, giving high yields of the corresponding carbonyl compounds (58).

The oxidation of primary and secondary alcohols to the corresponding carbonyl compounds has been most frequently accomplished in synthetic practice by the use of Cr(VI) reagents in amounts ranging from stoichiometric to large excess over stoichiometric (59). A new and highly effective reagent combination for the catalytic oxidation of secondary alcohols to ketones has been used (60). This reagent consisted of peroxyacetic acid as the stoichiometric oxidant and a catalytic amount of 2,4-dimethylpentane-2,4-diol cyclic chromate, using carbon tetrachloride-dichloromethane mixtures as solvent. A solution of the chromate ester was prepared from 2,4-dimethylpentane-2,4-diol and chromium trioxide in dry carbon tetrachloride. The yields of the corresponding ketones were almost quantitative, using this method (60).

A new class of Cr(VI) reagents derived from chromium trioxide and halosilanes has been developed. These reagents are highly efficient for the oxidation of alcohols to carbonyl compounds, for the oxidative coupling of mercaptans into disulfides, and for a mild cleavage of oximes to carbonyl compounds. Chlorotrimethylsilane-chromium trioxide has been shown to be an efficient oxidizing agent for the conversion of arylmethanes to benzaldehyde, and for the oxidative cleavage of some benzyl esters (61).

The use of a triazole to mediate selective Cr(VI) oxidation has been described. Benzotriazole, when used in conjunction with pyridinium chlorochromate in
dichloromethane, was found to be a mild and useful reagent system for the rapid and selective oxidation of steroidal allylic alcohols to the corresponding ketones (62). A new method for the 1,4-oxygenation of 1-alkylated cyclo-pentadienes had made use of 2-cyanopyridinium chlorochromate and powdered molecular sieves, in dichloromethane, to give the corresponding cyclopentenones in good yields (63).

Two new Cr(VI) reagents derived from nicotinic acid and isonicotinic acid were prepared (64). 3-Carboxypyridinium dichromate (nicotinium dichromate, NDC) and 4-carboxylpyridinium dichromate (isonicotinium dichromate, INDC), were synthesized from chromium trioxide dissolved in a small amount of water, and nicotinic or isonicotinic acid respectively. These two reagents (NDC and INDC) have been used for the oxidations of allylic and benzylic alcohols to aldehydes, thiols to disulfides, hydroquinones to benzoquinones, and for the oxidation of polynuclear aromatic hydrocarbons (64). This reagent, 3-carboxypyridinium dichromate (NDC), proved to be an efficient reagent for the oxidation of alcohols to carbonyl compounds, in the presence of pyridine. In order to ensure complete oxidation of the substrate, the optimum molar ratio of substrate : oxidant : pyridine was found to be 1 : 2.5 : 20, respectively (65).

The efficient oxidation of alcohols to carbonyl compounds under mild conditions has been a necessary theme in organic syntheses. An improved procedure was described for the extremely rapid and efficient oxidation of alcohols, by the addition of a small quantity of anhydrous acetic acid to pyridinium dichromate (PDC) and freshly activated molecular sieve powder, in dichloromethane, at room temperature (66).
Chromium peroxide complexes have been used as general oxidants in organic syntheses. 2,2-Bipyridylchromium peroxide has been used to convert different classes of alcohols to the carbonyl compounds, for C-C bond cleavages in 1,2-diols, the quantitative decarboxylation of α-hydroxy acids, the conversion of oximes to their carbonyl compounds, thiols to disulfides, dihydroxy phenolic compounds to quinones, benzylation to benzaldehyde, aromatic amines to their azo compounds, and for the conversion of anthracene and phenanthrene to their quinones (67). Pyridine chromium peroxide has been used to convert different classes of alcohols to the carbonyl compounds, thiols to disulfides, anthracene to anthraquinone, and for the decarboxylation of mandelic and benzylic acids (67). Chromium peroxide etherate has also been used as an effective reagent for the oxidation of different classes of alcohols to their respective carbonyl compounds (67).

Under mild conditions, imidazolium dichromate (IDC), in dimethylformamide as solvent, was found to be a useful and selective reagent for the oxidation of allylic and benzylic alcohols to the corresponding carbonyl compounds, the yields being very good (68).

A phase-transfer catalysis (PTC) technique for the oxidation of benzylic, primary and secondary alcohols was reported. Benzyltriethylammonium chlorochromate, generated in situ under phase-transfer conditions, was used in refluxing chloroform to oxidize alcohols to the corresponding carbonyl compounds in good yields (69).
Pyridinium bromochromate (PBC), in chloroform, was found to be an efficient reagent for the oxidation of benzyl alcohols, fluorenols and benzoin, giving good yields of the respective products (70).

Biphosphonium dichromate \((\text{C}_6\text{H}_3)_3\text{P}^+\text{CH}_2\text{P}^+(\text{C}_6\text{H}_3)_3\text{Cr}_2\text{O}_7^{2-}\), was a particularly mild and selective reagent for the oxidation of primary and secondary alcohols. The oxidation of primary alcohols to aldehydes occurred without further oxidation to acid, and without any isomerization or migration of the double bond (71).

Zinc dichromate trihydrate \([\text{ZnCr}_2\text{O}_7.3\text{H}_2\text{O}]\), in dichloromethane, was found to be a mild reagent for the oxidation of primary and secondary alcohols to the corresponding aldehydes and ketones in good yields. Allyl alcohols and tricyclic allyl alcohols were observed to be resistant towards any reaction with this reagent (72).

Catalytic amounts of chromium trioxide and excess of aqueous t-butyl hydroperoxide, was found to be an effective reagent for the conversion of alcohols to carbonyl compounds, geraniol having been converted to geranial at room temperature in quantitative yields (73).

The pyridinium dichromate induced oxidative rearrangement of various enynols proceeded with complete regiospecificity giving good yields. In these rearrangements, it was observed that chromate ester formation and subsequent ring flip created severe 1,4-steric (flag pole) interaction (74).

The oxidation of alcohols by pyridinium fluorochromate (PFC) in dichloromethane had yielded the corresponding carbonyl compounds in good yields. This study
indicated that PFC was an efficient two-electron oxidant which was capable of participating in oxygen-transfer reactions (75). The versatility of PFC as an oxidizing agent has been brought out by the various studies which have been carried out on the oxidation of some organic substrates such as aliphatic alcohols (76), sulfides (77), and aromatic alcohols (78).

Cyano-pyridinium chlorochromate (CPCC), in dichloromethane, was found to be the reagent of choice for the conversion of alkenes to α-chloroketones, and this procedure seemed to have broad applicability (79).

Pyridinium chlorochromate (PCC), in the presence of sodium azide or sodium cyanide, was used to transform aldehydes into carbamoyl azides or acyl azides in fairly good yields (80).

Cr(VI)-oxide diperoxide has been used for the oxidation of tertiary amines. These reactions were carried out in chloroform, and the products obtained were the corresponding N-oxides in good yields. The rate law observed suggested a mechanism involving a preliminary coordination of the amine to the metal. The oxidation rate of the amines and some organic sulfides indicated a mechanism having some single-electron-transfer (SET) character (81).

By using the ultrasound technique (82), pyridinium chlorochromate in conjunction with silica gel was developed as a heterogeneous process for the oxidation of alcohols to the corresponding carbonyl compounds (83). Using this process, borneol was converted to camphor, and geraniol was converted to geranial in excellent yields.
The synthetic utility of pyridinium chlorochromate in chloroform was demonstrated for the oxidation of alcohols, using anhydrous acetic acid as a catalyst (84). Such anhydrous conditions have been used for the oxidation of primary and secondary alcohols by pyridinium chlorochromate (84).

With a view to provide further evidence so as to ascertain the mechanism of the oxidation of alcohols by Corey’s reagent (PCC), two new Cr(VI) reagents were synthesized. These two reagents were 1-methyl imidazolium chlorochromate (MCC) and imidazolium chlorochromate (ICC). It was found that these two reagents were similar in selectivity. The mechanism for the oxidation of alcohols by these reagents was similar to that for the oxidation of the alcohols by PCC (85).

Benzotriazole was found to complex with chromium trioxide to produce a versatile new oxidant. This complex was capable of oxidizing primary alcohols to carboxylic acids, secondary alcohols to ketones, and olefin substrates to \( \alpha,\beta \)-unsaturated ketones by allylic oxidation (86). Farnesol could be converted to the corresponding acid. Other amine-CrO\(_3\) complexes have been reported to produce aldehydes from primary alcohols.

The oxidation of alcohols by isoquinolinium chlorochromate, in dichloromethane solvent, yielded the corresponding carbonyl compounds in reasonably good yields (87).

Three new Cr(VI) reagents (ferric dichromate, polyvinylpyridine supported zinc dichromate, and polyvinylpyridine supported ferric dichromate), were prepared and found to be stable, mild and efficient reagents for the oxidation of different kinds of organic compounds (88). Of these three reagents, ferric dichromate seemed to be the
most efficient. When taken in acetonitrile, ferric dichromate was able to oxidize styrene to benzaldehyde, and alcohols to their corresponding carbonyl compounds in good yields (88).

The oxidation of secondary alcohols with chromium trioxide, in the presence of wet aluminium oxide in hexane, had yielded the corresponding ketones. This method was used for the oxidation of cyclic alcohols, giving good yields of the cyclic ketones. For the oxidation of geraniol by this reagent, it was observed that the reaction proceeded without any appreciable loss of double bond stereochemistry (89).

The synthetic potential of quinolinium fluorochromate (QFC), C₉H₇NH[CrO₃F], and its application in the oxidation of alcohols was reported. This reagent was found to be as effective as pyridinium chlorochromate (PCC) and pyridinium fluorochromate (PFC). The major improvements have been the relatively higher solubility of QFC in non-aqueous solvents and much less pronounced acidic character, as compared to PCC and PFC (90). The versatile nature of QFC has been highlighted by the diverse types of organic substrates which have been oxidized by it. QFC in chloroform has been used to oxidize alcohols, polycyclic arenes, triphenylphosphine, trimethylsilyl ether and diphenylsulfide, and the yields reported have been excellent (91).

Kinetic studies involving the use of various chromium(VI) reagents have been reported. Pyridinium bromochromate has been employed for the kinetics of oxidation of phosphinic, phenylphosphinic and phosphorus acid (92). Pyridinium fluorochromate (PFC), in aqueous acetic acid medium, was found to be an efficient oxidant for the oxidation of secondary alcohols (93). Pyridinium chlorochromate (Corey's reagent) has
been extensively employed for the oxidation of different organic substrates. In the oxidation of cinnamic acids by this reagent, kinetic data has been used to support the mechanistic pathway for this reaction, which was characterized by a non-linear Hammett plot (94). The reaction of hydromates and hydroxyacids with pyridinium chlorochromate (PCC), in acid medium, catalysed by ruthenium(III), yielded kinetic data which suggested a mechanism involving an electron transfer reaction (95). Kinetic studies on the oxidation of some thioacids by 2,2'-bipyridinium chlorochromate has been reported (96). Quinolinium bromochromate has been selectively used for the oxidation of different alcohols in anhydrous acetic acid (97). A new chromium(VI) reagent, tetraethylammonium chlorochromate (TEACC), was introduced, and a kinetic study has been carried out on the oxidation of benzyl alcohol by this reagent in dimethylformamide solvent (98).

Quinolinium chlorochromate (QCC) was prepared by treating a solution of CrO₃ in 6M HCl with quinoline at 0 °C. The orange-red compound was stable when exposed to air, moisture and light. It efficiently oxidized primary and secondary alcohols to the corresponding carbonyl compounds (99).

Butyltriphenylphosphonium dichromate (BTPPD) was found to be a mild and selective oxidizing agent which was used for the oxidation of alcohols to carbonyl compounds, thiols to disulphides, aromatic amines to azo compounds, and aromatic oximes to the corresponding carbonyl compounds (100).
Isoquinolinium fluorochromate (IFC) was introduced as a new and efficient oxidant which was used for the oxidation of different organic substrates such as alcohols and aldehydes (101).

A new and selective oxidant, isoquinolinium dichromate (IDC), was found to be an efficient reagent for the oxidation of primary and secondary alcohols to the corresponding carbonyl compounds (102).

Imidazolinium fluorochromate was found to be a mild, stable and selective chromium(VI) reagent which was used for the oxidation of alcohols to the corresponding carbonyl compounds (103).

Benzyltriphenylphosphonium chlorochromate (BTPPC) was a mild and novel reagent which was used for the oxidation of benzylic and allylic alcohols under non aqueous and aprotic conditions (104).

Quinolinium dichromate (QDC), having the structure \((\text{C}_9\text{H}_7\text{N}^+\text{H})_2\text{Cr}_2\text{O}_7^{-}\), has been used for the oxidation of primary and secondary alcohols to aldehydes and ketones respectively, and for the oxidation of aldehydes to acids (105). QDC is a stable orange solid, which was prepared by dissolving \(\text{CrO}_3\) in water, adding quinoline, and collecting the product. Solutions of QDC, in dimethylformamide or suspensions in dichloromethane, have been used for the oxidation of alcohols and aldehydes, giving good yields of the corresponding products (105). A few representative examples of the oxidation of alcohols and aldehydes by QDC are given in Table 2.
Quinolinium dichromate (QDC) has now emerged as a very useful and versatile oxidant, which is clearly deserving of widespread application. QDC in dimethylformamide-water mixtures, in the presence of acid, has been used for the oxidation of a variety of organic substrates. Some of the organic substrates which have been oxidized by QDC in acid medium, have included benzyl alcohols (106), arylalkanes (107), diphenylamines (108), polynuclear aromatic hydrocarbons (109,110), toluene and substituted toluenes (110,111), fluorene (112), amino acids (113), benzoin (114), styrenes (115), unsaturated acids (116), bicyclic alcohols (117), cyclic alcohols (118), diols (119, 120), allylic alcohols (121), primary and secondary alcohols (122,
123), α-hydroxy acids (124, 125), benzyl amines (126), anilines (127), cyclic ketones (128), and α-keto acids (129). All these reactions using QDC have highlighted the kinetic features associated with the oxidation process, and mechanistic pathways have been suggested for all these oxidation reactions (106-129).
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