Research Article

Two New 1,1,3,3-Tetramethylguanidinium Halochromates ($C_5H_{14}N_3CrO_3X$) (X: Cl, F): Efficient Reagents for Oxidation of Organic Substrates under Solvent-Free Conditions and Microwave Irradiation

Kıvılcım Şendil,¹ H. Beytiye Özgün,² and Ebru Üstün²

¹Department of Chemistry, Faculty of Science, Kafkas University, 36100 Kars, Turkey

²Department of Chemistry, Faculty of Science, Gazi University, 06100 Ankara, Turkey

Correspondence should be addressed to Kıvılcım Şendil; kivilcimsendil@hotmail.com

Received 27 January 2016; Revised 27 March 2016; Accepted 11 April 2016

Academic Editor: Cristina Femoni

Copyright © 2016 Kıvılcım Şendil et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Two new mild oxidizing agents 1,1,3,3-tetramethylguanidinium fluorochromate (TMGFC) and 1,1,3,3-tetramethylguanidinium chlorochromate (TMGCC) were prepared in high yields by reacting tetramethylguanidine with CrO_3 and related acid. These reagents are suitable to oxidize various primary and secondary alcohols and oximes to the corresponding carbonyl compounds under solvent-free conditions and microwave irradiation.

1. Introduction

Oxidation of various organic compounds under mild conditions is of great importance in synthetic organic chemistry [1]. Chromium(VI) is the most widely employed among oxidizing agents based upon higher-valent transition metal oxo derivatives such as reagents derived from ruthenium, osmium, manganese, and vanadium. Since the appearance of Collins reagent [2], significant improvements are achieved in the development of new Cr(VI) based oxidizing agents for the effective and selective oxidation of organic substrates, in particular alcohols, under mild conditions. Some of the important entries in the list of reagents are pyridinium chlorochromate (PCC) [3], pyridinium dichromate (PDC) [4], pyridinium fluorochromate (PFC) [5, 6], quinolinium fluorochromate (QFC) [7], 1,1,3,3-tetramethylguanidinium dichromate (TMGDC) [8], quinolinium chlorochromate (QCC) [9], and 3,5-dimethylpyrazolium fluorochromate (DmpzHFC) [10]. However the chromium based reagents that have been developed so far have some limitations that cannot be overlooked. These include the inherent problems of acidity of the reagents, instability, tedious work-up, a long

reaction time, overoxidation, use of toxic solvent, or a need for excess amount of reagent [11–18]. Consequently, there is still scope for the search of highly efficient and mild oxidizing agents.

Recently considerable attention has been paid to solvent-free reactions [19]. These reactions not only are of interest from an ecological point of view, but in many cases also offer considerable synthetic advantages in terms of yield, selectivity, and simplicity of the reaction procedure. In recent years organic reactions assisted by microwave irradiation have gained special attention [20]. Microwave assisted organic transformations coupled with solvent-free conditions have attracted much attention due to enhanced reaction rates, easier work-up, and facilitated purification [21–24].

In continuation of our ongoing research program for developing newer chromium reagents [25–28], two new oxidizing agents such as 1,1,3,3-tetramethylguanidinium fluorochromate (TMGFC) and 1,1,3,3-tetramethylguanidinium chlorochromate (TMGCC) shown in Figure 1 were synthesized with the belief that these reagents could be used for the oxidation of organic substrates.

FIGURE 1

2. Experimental

All reagents and solvents were obtained from Aldrich and used without further purification. The ^1H NMR spectrum was recorded on a Bruker Avance 300-MHz spectrometer (Germany). Elemental analysis was performed using an Elemental Micro Vario CHNS. Electrothermal melting points were determined by a 9200 digital melting point apparatus (United Kingdom) and are uncorrected. IR spectra were recorded on a Mathson 1000 FT-IR spectrometer. All microwave irradiation reactions were carried out on a Milestone Micro-Synth apparatus.

2.1. Preparation of 1,1,3,3-Tetramethylguanidinium Fluorochromate (TMGFC). Chromium(IV)oxide (CrO_3) (20 mmol, 2 g) was taken in a polyethylene beaker and 48% hydrofluoric acid (HF) (23 mmol, 1.1 mL) was added dropwise with continuous stirring for 10 min. The orange solution thus obtained was cooled in an ice-bath. To this solution 1,1,3,3-tetramethylguanidine (20 mmol, 2.5 mL) was added portion-wise in 15 min. The mixture was kept at -10°C for 1 hour. The orange amorphous solid thus formed was filtered off, washed twice with hexane, and dried under vacuum for 1 h. Yield: 85%, mp: $130\text{--}131^\circ\text{C}$; ^1H NMR (300 MHz, DMSO-d_6): $\delta = 2.9$ (s, 3H), $\delta = 7.78$ (s, 2H, $-\text{NH}_2$), IR (KBr): $\nu = 951\text{ cm}^{-1}$ ($\text{Cr}=\text{O}$), 771 cm^{-1} ($\text{Cr}=\text{O}$), 539 cm^{-1} (Cr-F); Elemental Analysis ($\text{C}_5\text{H}_{14}\text{N}_3\text{CrO}_3\text{F}$): (Calculated): 25.53 (C%); 5.96 (H%); 17.94 (N%); (Found): 26.16 (C%); 6.49 (H%); 18.14 (N%).

2.2. Preparation of 1,1,3,3-Tetramethylguanidinium Chlorochromate (TMGCC). Chromium(IV)oxide (CrO_3) (20 mmol, 2 g) was taken in a polyethylene beaker and 6 M hydrochloric acid (HCl) (20 mmol, 3.6 mL) was added dropwise with continuous stirring for 10 min. The orange solution thus obtained was cooled in an ice-bath. To this solution 1,1,3,3-tetramethylguanidine (20 mmol, 2.5 mL) was added portion-wise in 15 min. The mixture was kept at -10°C for 1 hour. The orange amorphous solid thus formed was filtered off, washed twice with hexane, and dried under vacuum for 1 h. Yield: 75%, mp: $136\text{--}137^\circ\text{C}$; ^1H NMR (300 MHz, DMSO-d_6): $\delta = 2.9$ (s, 3H), $\delta = 7.75$ (s, 2H, $-\text{NH}_2$), IR (KBr): $\nu = 951\text{ cm}^{-1}$ ($\text{Cr}=\text{O}$), 778 cm^{-1} ($\text{Cr}=\text{O}$), 458 cm^{-1} (Cr-Cl); Elemental Analysis ($\text{C}_5\text{H}_{14}\text{N}_3\text{CrO}_3\text{Cl}$): (Calculated): 23.90 (C%); 5.58 (H%); 16.73 (N%); (Found): 24.99 (C%); 5.62 (H%); 16.85 (N%).

2.3. General Procedure for the Oxidation under Solvent-Free Conditions. The oxidant (1.5–2 mmol) was added to the substrate (1 mmol) in a mortar. Starting materials were instantly

mixed, ground, and kept for the appropriate period at room temperature or in an oven without any further agitation. The progress of the reaction was monitored by using TLC on silica gel (benzene:ethyl acetate = 9:1). Upon completion of the reaction, extraction with ether ($3 \times 25\text{ mL}$) and evaporation of the solvent gave the corresponding carbonyl compounds.

2.4. General Procedure for the Oxidation under Microwave Irradiation. The substrate (1 mmol) and 1.5–2 mmol oxidant were mixed. To this mixture 0.5 mL CH_2Cl_2 was added. The mixture was subjected to microwave irradiation (1000 W). Upon completion of the reaction, extraction with ether ($3 \times 25\text{ mL}$) and evaporation of the solvent gave the corresponding carbonyl compounds. The products formed were analyzed by their 2,4-dinitrophenylhydrazones derivatives. The precipitated 2,4-DNP was filtered off, weighed, and recrystallized from ethanol.

3. Results and Discussion

1,1,3,3-Tetramethylguanidinium fluorochromate (TMGFC) and 1,1,3,3-tetramethylguanidinium chlorochromate (TMGCC) can easily be prepared in good yields by reacting tetramethylguanidine with CrO_3 and related acid at a molar ratio of 1:1:1 in aqueous medium.

TMGFC and TMGCC are orange colored stable amorphous solids at room temperature. They are moisture insensitive and can be stored in polyethylene containers for long periods without decomposition.

The pH values of 0.01 M aqueous solutions of PCC, PFC, TMGFC, and TMGCC were found to be 1.75, 2.45, 3.79, and 3.89. The higher pH values of TMGFC and TMGCC compared to their companion reagents attest to their far less pronounced acidic characters. So, TMGFC and TMGCC may be proper oxidizing agents for the oxidation of acid-sensitive compounds.

TMGFC and TMGCC are highly soluble in DMF and DMSO; slightly soluble in acetonitrile and dichloromethane; and insoluble in benzene, ether, chloroform, and toluene. These results are indicative of the ionic nature of the reagents.

The conductivity values of 10^{-3} M solutions of TMGFC and TMGCC in acetonitrile at 25°C were found as $140\text{ }\Omega^{-1}\text{cm}^2\text{mol}^{-1}$ and $150\text{ }\Omega^{-1}\text{cm}^2\text{mol}^{-1}$, respectively. So, they are 1:1 electrolytes.

The effect of substrate:oxidant molar ratios has been investigated by applying 1:1, 1:1.25, 1:1.5, and 1:2 molar ratios, respectively, for the oxidation of benzyl alcohol as a model substrate under solvent-free conditions at room temperature for 30 min. The yields thus obtained were given in Table 1.

SCHEME 1

SCHEME 2

TABLE 1: Oxidation of benzyl alcohol with different amounts of TMGCC and TMGFC.

Oxidants	Substrate : oxidants (molar ratio)	Yield ^a %
TMGCC	1:1	72
	1:1.25	74
	1:1.5	80
	1:2	86
TMGFC	1:1	75
	1:1.25	78
	1:1.5	85
	1:2	90

^aYields refer to the isolated 2,4-DNP derivative [29].

To show the influence of nature of solvent on the reactivity of the oxidants, various solvents such as CH_2Cl_2 , acetone, and DMF have been used for the oxidation of benzyl alcohol as representative substrate (Table 2).

The use of more polar solvents such as DMF and acetone resulted in moderate yields.

TABLE 2: Oxidation of benzyl alcohol in different solvents with TMGCC and TMGFC.

Solvents	Substrate : oxidation (molar ratio)	Reaction period/h	TMGCC Yield ^a %	TMGFC Yield ^a %
CH_2Cl_2	1:2	2	82	88
Acetone	1:2	2	63	70
DMF	1:2	2	60	65

^aYields refer to the isolated 2,4-DNP derivative [29].

In order to ascertain the efficiency of the reagents as oxidants, different types of primary and secondary alcohols and oximes were treated with the reagents by taking the molar ratio of substrate:oxidant as 1:1-2 under solvent-free conditions at room temperature and under microwave irradiation to afford the corresponding carbonyl compounds (Scheme 1).

A probable mechanism for the oxidation with TMGCC and TMGFC is given on the basis of previously reported mechanisms [30] (Scheme 2).

TABLE 3: The oxidation of alcohols and oximes with TMGFC under solvent-free conditions at room temperature and under microwave irradiation.

Entry	Substrate	Product	Yield% (time) ^a	
			Solvent-free (hour)	Microwave (second)
1	<chem>CH3(CH2)6CH2OH</chem>	<chem>CH3(CH2)6CHO</chem>	76 (4)	77 (10)
2	<chem>(H3C)3C-C6H10OH</chem>	<chem>(H3C)3C-C6H9=O</chem>	70 (4)	75 (13)
3	<chem>C6H11OH</chem>	<chem>C6H9=O</chem>	75 (3.5)	76 (13)
4	<chem>CH3-CH2-C(CH3)2-CH2-CH2-CH2OH</chem>	<chem>CH3-CH2-C(CH3)2-CH2-CH2-CHO</chem>	70 (4)	75 (10)
5	<chem>c1ccccc1C=CHCH2OH</chem>	<chem>c1ccccc1C=CHCHO</chem>	85 (0.5)	90 (5)
6	<chem>c1ccccc1CO</chem>	<chem>c1ccccc1C=O</chem>	90 (0.5)	92 (4)
7	<chem>COc1ccc(CO)cc1</chem>	<chem>COc1ccc(C=O)cc1</chem>	90 (1)	93 (7)
8	<chem>c1ccc(CO)cc1</chem>	<chem>c1ccc(C=O)cc1</chem>	85 (1)	89 (8)
9	<chem>Clc1ccc(CO)cc1</chem>	<chem>Clc1ccc(C=O)cc1</chem>	86 (1)	92 (9)
10	<chem>[O-][N+](=O)c1ccc(CO)cc1</chem>	<chem>[O-][N+](=O)c1ccc(C=O)cc1</chem>	87 (1.25)	88 (10)
11	<chem>c1ccccc1C(=O)C(O)c2ccccc2</chem>	<chem>c1ccccc1C(=O)C(=O)c2ccccc2</chem>	42 (4.5) (70 °C)	60 (10)
12	<chem>c1ccccc1C(O)c2ccccc2</chem>	<chem>c1ccccc1C(=O)c2ccccc2</chem>	85 (1)	85 (8)
13	Benzoin oxime	Benzoin	55 (8)	58 (10)
14	Cyclohexanone oxime	Cyclohexanone	70 (4)	75 (20)
15	Cyclopentanone oxime	Cyclopentanone	70 (7)	78 (10)

^aYield was based on 2,4-dinitrophenylhydrazone derivative identified by melting point [29] (except for the 4-nitrobenzaldehyde and benzil whose melting points were taken directly).

Primary benzylic alcohols and 1-octanol were converted into their corresponding aldehydes with good to high yields (Tables 3 and 4, entries 1 and 6–10). The oxidation of these alcohols is performed devoid of overoxidation. The reactivity of the aliphatic primary and secondary alcohols seemed to be slightly lower than benzylic alcohols (Tables 3 and 4, entries 1–4). It is also noteworthy that cinnamyl alcohol (Tables 3 and 4, entry 5) was converted to cinnamaldehyde without the cleavage of the benzylic double bond and the reaction is essentially chemoselective.

Aliphatic oximes such as cyclohexanone oxime and cyclopentanone oxime were deoximated more efficiently than benzoin oxime (Tables 3 and 4, entries 13–15). The oxidation

reactions of polycyclic aromatic hydrocarbons such as anthracene and phenanthrene were attempted by taking the molar ratio of substrate:oxidizing agent as 1:3 under microwave irradiation but the substrates remained intact.

During the reactions, the color of the oxidants changes from orange to brown, providing visual means for ascertaining the progress of the oxidation.

In order to show the oxidative ability of the reagents (TMGCC and TMGFC), we compared some of our results with those of PCC [20], PFC [31, 32], BAAOC [33], and DmpzHFC [34] carried out under solvent-free conditions (Table 5).

TABLE 4: The oxidation of alcohols and oximes with TMGCC under solvent-free conditions at room temperature and under microwave irradiation.

Entry	Substrate	Product	Yield% (time) ^a	
			Solvent-free (hour)	Microwave (second)
1	<chem>CH3(CH2)6CH2OH</chem>	<chem>CH3(CH2)6CHO</chem>	70 (4.5)	74 (11)
2	<chem>(H3C)3C-C6H10OH</chem>	<chem>(H3C)3C-C6H9O</chem>	75 (4)	75 (15)
3	<chem>C6H11OH</chem>	<chem>C6H9O</chem>	75 (3.5)	73 (14)
4	<chem>CH3-C6H10CH2OH</chem>	<chem>CH3-C6H9O</chem>	72 (5)	73 (10)
5	<chem>c1ccccc1CH=CHCH2OH</chem>	<chem>c1ccccc1CH=CHCHO</chem>	85 (1)	87 (8)
6	<chem>c1ccccc1CH2OH</chem>	<chem>c1ccccc1CHO</chem>	85 (1)	90 (7)
7	<chem>COc1ccc(CO)cc1</chem>	<chem>COc1ccc(C=O)cc1</chem>	91 (1)	89 (8)
8	<chem>c1ccc(CO)cc1</chem>	<chem>c1ccc(C=O)cc1</chem>	80 (2)	85 (11)
9	<chem>Clc1ccc(CO)cc1</chem>	<chem>Clc1ccc(C=O)cc1</chem>	85 (1.5)	84 (10)
10	<chem>O=[N+]([O-])c1ccc(CO)cc1</chem>	<chem>O=[N+]([O-])c1ccc(C=O)cc1</chem>	86 (1.5)	85 (11)
11	<chem>c1ccccc1C(=O)C(O)c2ccccc2</chem>	<chem>c1ccccc1C(=O)C(=O)c2ccccc2</chem>	40 (6) (70 °C)	50 (10)
12	<chem>c1ccccc1C(O)Cc2ccccc2</chem>	<chem>c1ccccc1C(=O)Cc2ccccc2</chem>	82 (1)	86 (10)
13	Benzoin oxime	Benzoin	50 (9)	54 (10)
14	Cyclohexanone oxime	Cyclohexanone	71 (4.5)	74 (22)
15	Cyclopentanone oxime	Cyclopentanone	72 (8.5)	72 (10)

^aYield was based on 2,4-dinitrophenylhydrazone derivative identified by melting point [29] (except for the 4-nitrobenzaldehyde and benzil whose melting points were taken directly).

TABLE 5: Comparison of oxidation of various organic substrates by TMGCC, TMGFC, PCC, PFC, BAAOC, and DmpzHFC.

Substrate	Yield% (time [min])					
	TMGCC	TMGFC	PCC [20]	PFC [31, 32]	BAAOC [33]	DmpzHFC [34]
4-Methoxybenzyl alcohol	91 (1)	90 (1)	94 (5)	89 (10)	99 (2)	92 (2)
4-Chlorobenzyl alcohol	85 (1.5)	86 (1)	93 (10)	78 (10)	95 (7)	—
Benzyl alcohol	85 (1)	90 (0.5)	96 (15)	93 (10)	98 (1)	85 (1)
Cinnamyl alcohol	85 (1)	85 (0.5)	95 (15)	85 (10)	85 (20)	89 (2)

4. Conclusion

In conclusion, we have developed two new reagents TMGFC and TMGCC for the oxidation of alcohols and oximes. We

described a solvent-free and a highly efficient microwave induced procedure for the rapid synthesis of aldehydes and ketones. These transformations enjoy the chemical and environmental advantages of solvent-free reactions. The results

obtained are satisfactory and show the new reagents to be valuable additions to the existing agent.

Competing Interests

The authors declare that they have no competing interests.

References

- [1] F. A. Luzzio and F. S. Guziec, "Recent applications of oxochromiumamine complexes as oxidants in organic synthesis. A review," *Organic Preparations and Procedures International*, vol. 20, no. 6, pp. 533–584, 1988.
- [2] J. C. Collins, W. W. Hess, and F. J. Frank, "Dipyridine-chromium(VI) oxide oxidation of alcohols in dichloromethane," *Tetrahedron Letters*, vol. 9, no. 30, pp. 3363–3366, 1968.
- [3] E. J. Corey and J. W. Suggs, "Pyridinium chlorochromate. An efficient reagent for oxidation of primary and secondary alcohols to carbonyl compounds," *Tetrahedron Letters*, vol. 16, no. 31, pp. 2647–2650, 1975.
- [4] E. J. Corey and G. Schmidt, "Useful procedures for the oxidation of alcohols involving pyridinium dichromate in aprotic media," *Tetrahedron Letters*, vol. 20, no. 5, pp. 399–402, 1979.
- [5] M. N. Bhattacharjee, M. K. Chaudhuri, H. S. Dasgupta, N. Roy, and D. T. Khathing, "Pyridinium fluorochromate; a new and efficient oxidant for organic substrates," *Synthesis*, vol. 1982, no. 7, pp. 588–590, 1982.
- [6] M. N. Bhattacharjee, M. K. Chaudhuri, and S. Purkayastha, "Some aspects of pyridinium fluorochromate, $C_5H_5NHCrO_3F$ (PFC), oxidations. stoichiometry of oxidation of alcohols, evidence for oxygen transfer, and the identity of the reduced chromium species," *Tetrahedron*, vol. 43, no. 22, pp. 5389–5392, 1987.
- [7] M. K. Chaudhuri, S. K. Chettri, S. Lyndem, P. C. Paul, and P. Srinivas, "Quinolinium fluorochromate (QFC), $C_9H_7NH(CrO_3F)$: an improved Cr(VI)-oxidant for organic substrates," *Bulletin of the Chemical Society of Japan*, vol. 67, no. 7, pp. 1894–1898, 1994.
- [8] S. Goswami and A. Kar, "Guanidinium chlorochromate, a new, efficient, and mild oxidizing agent for benzylic and other alcohols to carbonyl compounds in water and organic solvents," *Synthetic Communications*, vol. 41, no. 17, pp. 2500–2504, 2011.
- [9] R. Srinivasan, C. V. Ramesh, W. Madhulatha, and K. Balasubramanian, "Oxidation of alcohols by quinolinium chlorochromate," *Indian Journal of Chemistry B: Organic Chemistry including Medicinal*, vol. 35B, pp. 480–481, 1996.
- [10] U. Bora, M. K. Chaudhuri, D. Dey, D. Kalita, W. Khar-mawphlang, and G. C. Mandal, "3,5-Dimethylpyrazolium fluorochromate(VI), $C_5H_8N_2H[CrO_3F]$, (DmpzHFC): a convenient new reagent for oxidation of organic substrates," *Tetrahedron*, vol. 57, no. 12, pp. 2445–2448, 2001.
- [11] G. Maier, H. P. Reisenauer, and M. De Marco, "Isonitroso hydrogen (hydroxy nitrene, HON)," *Angewandte Chemie—International Edition*, vol. 38, no. 1-2, pp. 108–110, 1999.
- [12] A. Bhandari, P. K. Sharma, and K. K. Banerji, "Kinetics and mechanism of the oxidative regeneration of carbonyl compounds from oximes by pyridinium chlorochromate," *Indian Journal of Chemistry—Section A: Inorganic, Physical, Theoretical and Analytical Chemistry*, vol. 40, no. 5, pp. 470–474, 2001.
- [13] S. Meenakshisundaram and R. Sockalingam, "Kinetics and mechanism of the quinolinium fluorochromate oxidation of some primary, secondary and unsaturated alcohols in acetonitrile," *Collection of Czechoslovak Chemical Communications*, vol. 66, no. 6, pp. 877–896, 2001.
- [14] J. H. Clark, S. R. Cullen, S. J. Barlow, and T. W. Bastock, "Environmentally friendly chemistry using supported reagent catalysts—structure-property relationships for clayzic," *Journal of the Chemical Society, Perkin Transactions 2*, no. 6, pp. 1117–1130, 1994.
- [15] R. S. Varma, R. Dahiya, and R. K. Saini, "Iodobenzene diacetate on alumina: rapid oxidation of alcohols to carbonyl compounds in solventless system using microwaves," *Tetrahedron Letters*, vol. 38, no. 40, pp. 7029–7032, 1997.
- [16] J.-D. Lou, L.-H. Zhu, L.-L. Pan, L. Li, F. Li, and C.-L. Gao, "Solvent-free oxidation of secondary alcohols with chromium trioxide," *Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry*, vol. 36, no. 7, pp. 585–587, 2006.
- [17] J.-D. Lou and L.-Z. Wang, "An efficient and selective solvent-free oxidation of alcohols," *Chemical Papers*, vol. 57, no. 2, pp. 136–137, 2003.
- [18] M. Tajbakhsh, R. Hosseinzadeh, and M. Sadatshahabi, "Synthesis and application of 2,6-Dicarboxy pyridinium fluorochromate as a new solid-phase oxidant," *Synthetic Communications*, vol. 35, no. 11, pp. 1547–1554, 2005.
- [19] A. Saffar-Teluri, "Fast selective oxidation of alcohols under solvent-free conditions," *Research on Chemical Intermediates*, vol. 39, no. 7, pp. 3337–3343, 2013.
- [20] P. Salehi, H. Firouzabadi, A. Farrokhi, and M. Gholizadeh, "Solvent-free oxidations of alcohols, oximes, aldehydes and cyclic acetals by pyridinium chlorochromate," *Synthesis*, no. 15, pp. 2273–2276, 2001.
- [21] K. Tanaka and F. Toda, "Solvent-free organic synthesis," *Chemical Reviews*, vol. 100, no. 3, pp. 1025–1074, 2000.
- [22] M. M. Kazem, G. Shahriare, and I. Hossein, "Microwave-assisted oxidation of alcohols and polyarenes with cetyltrimethylammonium bromochromate," *Chinese Journal of Chemistry*, vol. 27, no. 8, pp. 1501–1504, 2009.
- [23] J. Einhorn, C. Einhorn, F. Ratajczak, and J.-L. Pierre, "Efficient and highly selective oxidation of primary alcohols to aldehydes by N-chlorosuccinimide mediated by oxoammonium salts," *Journal of Organic Chemistry*, vol. 61, no. 21, pp. 7452–7454, 1996.
- [24] L. Ross A and D. S. Donald, "Magtrieve™: an efficient, magnetically retrievable and recyclable oxidant," *Tetrahedron Letters*, vol. 38, no. 22, pp. 3857–3860, 1997.
- [25] B. Özgün and K. Şendil, "Quinoxalium Fluorochromate (QxFC): a new and efficient reagent for the oxidation of alcohols in solution, under solvent-free conditions and microwave irradiation," *Phosphorus, Sulfur and Silicon and the Related Elements*, vol. 181, no. 4, pp. 959–964, 2006.
- [26] B. Özgün, A. Yaylaoglu, and K. Şendil, "4-Benzylpyridinium fluorochromate: an efficient and selective oxidant for organic substrates," *Monatshefte für Chemie*, vol. 138, no. 2, pp. 161–163, 2007.
- [27] K. Şendil and B. Özgün, "Dipyrazinium Tri(fluorotrioxochromate): an efficient oxidant for organic substrates," *Monatshefte für Chemie*, vol. 137, no. 12, pp. 1529–1533, 2006.
- [28] M. Canbulat and B. Özgün, "3,5-Dimethylpyrazolium chlorochromate(VI): an efficient reagent for solvent-free oxidation of organic substrates," *Synthesis and Reactivity in Inorganic, Metal-Organic and Nano-Metal Chemistry*, vol. 42, no. 5, pp. 634–637, 2012.

- [29] Z. Rapport, *Handbook of Tables for organic Compounds Identification*, CRC Press, Boca Raton, Fla, USA, 3rd edition, 1976.
- [30] E. J. Corey and D. L. Boger, "Oxidative cationic cyclization reactions effected by pyridinium chlorochromate," *Tetrahedron Letters*, vol. 19, no. 28, pp. 2461–2464, 1978.
- [31] M. K. Chaudhuri, S. K. Dehury, S. S. Dhar, and U. B. Sinha, "The economic synthesis of pyridinium fluorochromate (VI), $C_5H_5NH[CrO_3]$ (PFC), and solvent-free oxidation of organic substrates with PFC," *Synthetic Communications*, vol. 34, no. 22, pp. 4077–4087, 2004.
- [32] K. Şendil, *Synthesis and characterization of some oxochromdi-chromates, halochromates, investigation of oxidation reactions of various organic compounds in different mediums [Ph.D. thesis]*, 2005, <https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp>.
- [33] A. R. Hajipour, H. R. Bagheri, and A. E. Ruoho, "Solid state oxidation of alcohols using 1-butyl-4-aza-1-azoniabicyclo[2.2.2]octane chlorochromate," *Bulletin of the Korean Chemical Society*, vol. 25, no. 8, pp. 1238–1240, 2004.
- [34] M. K. Chaudhuri, S. K. Dehury, S. Hussain, A. Duarah, and N. Gogoi, "The selective solid-phase oxidation of alcohols and other organic substrates by 3,5-dimethylpyrazolium Fluorochromate," *Organic Preparations and Procedures International*, vol. 38, no. 3, pp. 331–336, 2006.