

CHEMISTRY & BIOLOGY INTERFACE

An official Journal of ISCB, Journal homepage; www.cbijournal.com

An Efficient and Solvent-Free Approach for the Synthesis of Dithiocarbamates from Their Corresponding Alcoholic Tosylates

Sadaf Zaidi,^a Amit K. Chaturvedi,^b Mridula Saxena,^a Devdutt Chaturvedi,^{c,*}

^aDepartment of Applied Chemistry, Amity School of Applied Sciences, Amity University Uttar Pradesh (AUUP), Lucknow Campus, Lucknow-226028, U. P.

^bDepartment of Chemistry, J. S. University, Shikohabad-283135, Firozabad, U. P., India.

^cDepartment of Chemistry, School of Physical & Material Sciences, Mahatma Gandhi Central University, Motihari-845401 (East Champaran), Bihar, India.

*Corresponding author's E-mail: devduttchaturvedi@gmail.com, devduttchaturvedi@mgcub.ac.in

Received 15 May 2017; Accepted 14 June 2017

Abstract: A novel one-pot, solvent-free method for the synthesis of dithiocarbamates was developed through the reaction of corresponding alcoholic tosylates, amines and carbon disulfide employing catalytic amount of benzyl trimethyl ammonium hydroxide (Triton-B). The reaction conditions are milder with extremely simple work-up procedures than the reported methods, afforded high yields (82-98%) of the desired products.

Keywords: Amines; Alcoholic tosylates; Carbon disulfide; Triton-B; Dithiocarbamates

1. Introduction

Organic dithiocarbamates have extensively been used as agrochemicals,¹ pharmaceuticals,² intermediates in organic synthesis,³ protection of amino groups in peptide chemistry,⁴ linkers in solid phase organic synthesis,⁵ radical precursors in free-radical chemistry⁶ and synthesis of ionic liquids.⁷ Furthermore, different transition metal complexes of dithiocarbamates have been synthesized for various studies, primarily because of their applications as organic superconductors.⁸ In recent years, dithiocarbamates have been emerged as a novel

class of potential agrochemicals (e. g. pesticides,⁹ herbicides,¹⁰ insecticides,¹¹ fungicides¹² etc.) such as carbamorph, ziram, benzothiazole derivatives etc. (Figure 1). As-pharmaceuticals, they have been used as drugs and prodrugs for the different type of biological activities such as anti-microbial,¹³ anticancer,¹⁴ antiprotozoal,¹⁵ antileprosy,¹⁶ antitubercular,¹⁷ anti-fungal,¹⁸ anti-alzheimer,¹⁹ and contraceptive agents²⁰ etc. (Figure 1). Furthermore, recently it has been realized through various published reports that by incorporating dithiocarbamate linkage into structurally diverse biologically potent synthetic/semisynthetic/natural molecules may lead to

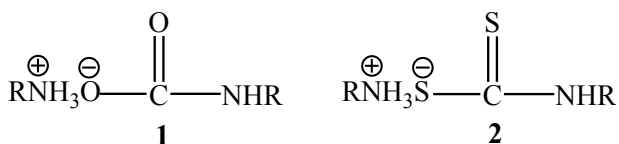
manifold increase in biological activities.²¹ As a useful synthon, organic dithiocarbamates have been extensively used for the synthesis of structurally diverse biological potent scaffolds such as isothiocyanates,²² thiourea,²³ cyanamide,²⁴ dithiobenzophene,²⁵ glycosides,²⁶ amide,²⁷ dicarboxylates,²⁸ benzimidazole,²⁹ carbamate,³⁰ pyran,³¹ flavonoids³² *etc.* In view of their tremendous importance and wide applications, their syntheses have gained considerable attention, and therefore have become a focus of synthetic organic chemistry.

Traditional synthesis of organic dithiocarbamates involves use of phosgene³³ and its derivatives.³⁴ However, these methods are associated with several drawbacks like use of costly and toxic reagents such as thiophosgene and its derivatives, longer reaction time and lesser yield. Therefore, their syntheses has been changed from harmful reagents to abundantly available, cheap and safe reagent like carbon disulfide.³⁵ However, their formation using carbon disulfide employed harsh reaction conditions such a use of strong bases, higher reaction temperatures and longer reaction times.³⁶ Therefore, there is still need for the development of safer and efficient synthetic protocols for the syntheses of dithiocarbamates. Our group has been engaged from past several years for the development of new methodologies for the preparation of carbamates, dithiocarbamates and related compounds using cheap, abundantly available and safe reagents like carbon dioxide and carbon disulphide respectively.³⁷ In recent years, we found that Triton-B has emerged as a best catalyst for the synthesis of carbamates, dithiocarbamates, carbazates, dithiocarbazates, dithiocarbonates employing a variety of reagents and catalytic systems.³⁸ In the present communication, we report here an efficient and novel, one-pot, solvent-free synthesis of dithiocarbamates starting from their corresponding alcoholic tosylates and amines employing Triton B/CS₂ system. The alcoholic tosylates of various primary, secondary and

tertiary alcohols were prepared from their corresponding alcohols following well known reported standard procedure.³⁹

2. Results and Discussion

In connection with our ongoing interest pertaining to the use of Triton-B for the synthesis of carbamates, dithiocarbamates, carbazates, dithiocarbazates and dithiocarbonates (xanthates).³⁸ In the present paper, we wish to report a simple and effective one-pot procedure for the synthesis of dithiocarbamates, through the nucleophilic attack of S⁻ ion of monoalkylammonium alkyl dithiocarbamate ion (MAADC) **2** (Formulae 1) upon the carbocation generated from the electrophilic carbon of the corresponding alcoholic tosylates. Thus, a mixture of amine and CS₂ were taken without any solvent and Triton-B was added into it with constant stirring at room temperature. It has been reported by our group that by reacting two molar ratio of amine with carbon dioxide afforded the corresponding monoalkylammonium alkyl carbamate (MAAC) ion **1**, by adopting similar approach, monoalkylammonium alkyl dithiocarbamate (MAADC) ion **2** should be obtained through reaction of two molar equivalents of amine with CS₂ (Formulae 1). Since CS₂ is more reactive than CO₂, therefore the-



Formulae

-reaction was tried at room temperature. It has been observed that the nucleophilicity of S⁻ of MAADC ion **2** could be increased by using basic phase transfer catalyst (PTC) like Triton-B. The nucleophilic attack of S⁻ of MAADC ion **2** to the electrophilic carbon of the corresponding alkyl halide may led to afford the corresponding

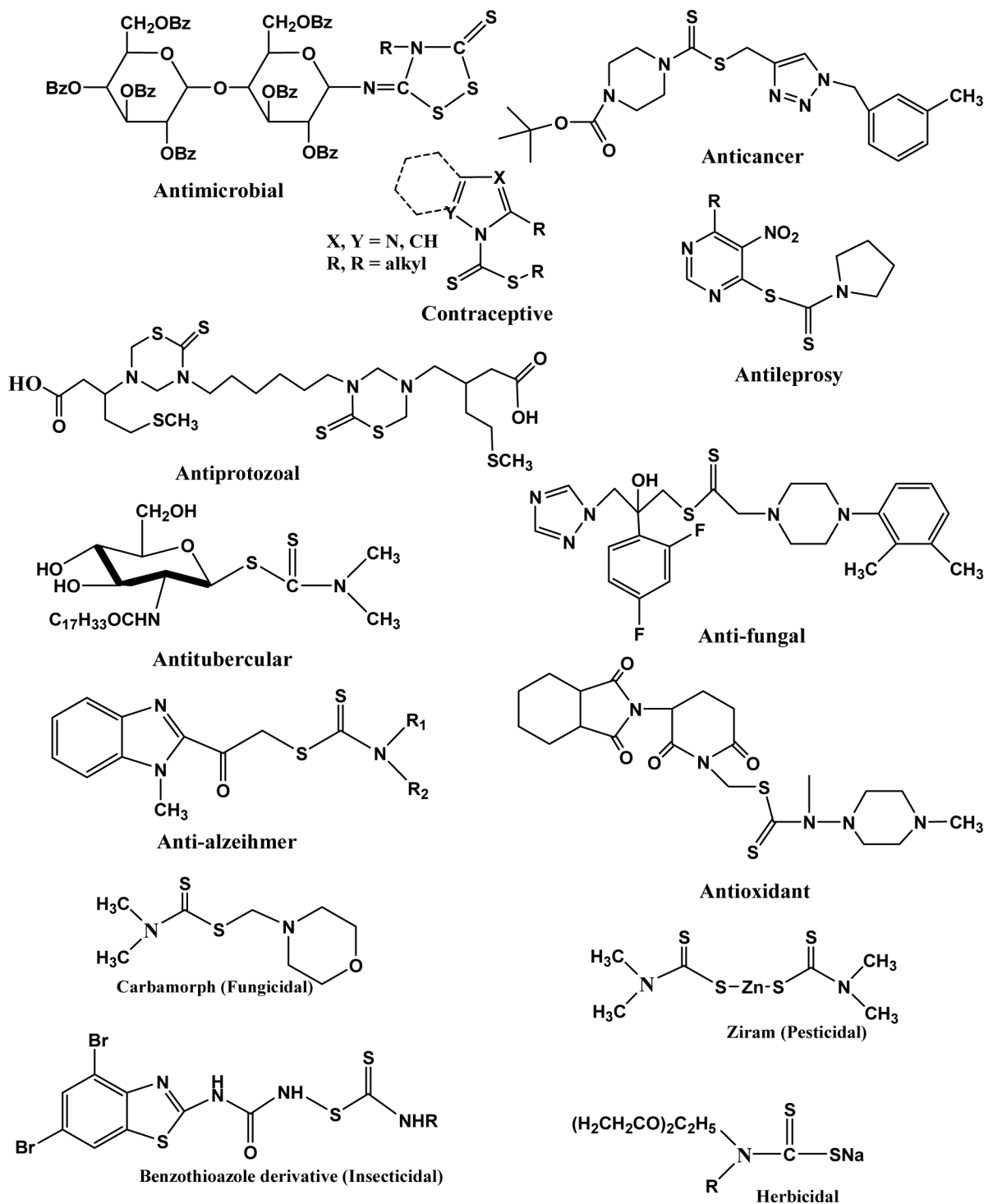


Figure 1: Various kinds of structurally diverse biologically potent dithiocarbamates

dithiocarbamate. The confirmation of product- was made based on the spectroscopic and analytical data with our previously synthesized authentic dithiocarbamate. It is important to note here that amine used for this reaction should have at least one available hydrogen atom to help in the formation of MAAADC ion **2**. Therefore, this reaction could not be successful for the dithiocarbamates from tertiary amines which do not have atleast one hydrogen atom.

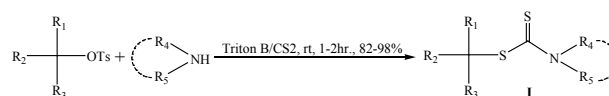
In order to study the effects of various phase transfer catalysts (PTC) on the yield of the reaction, a reaction of tosylate of phenyl ethyl alcohol with *n*-butyl amine employing various phase transfer catalysts (PTC) such as tetra-*n*-butyl ammonium iodide (TBAI), tetra-*n*-butyl ammonium bromide (TBAB), tetra-*n*-butyl ammonium chloride (TBAC), tetra-*n*-butyl ammonium hydrogen sulfate (TBAHS), tetra-*n*-butyl ammonium hydrogen carbonate (TBAHC), and benzyl trimethyl ammonium hydroxide (Triton-B) etc. was tried and we found that Triton-B was found to best in achieving the high yields of the desired dithiocarbamates (Table 1).

Table 1: Effect of various phase transfer catalysts on the yield of dithiocarbamates

S. No.	Name of PTC	Time (hr.)	Yield (%)
1	TBAI	2	89
2	TBAB	2	88
3	TBAC	2.5	86
4	TBAHS	2.5	82
5	TBAHC	2	83
6	Triton B	1.5	91

After optimizing the reaction conditions, this reaction was employed to a variety of primary, secondary, and *tert*. Alcoholic tosylates with various kinds of primary, secondary

aliphatic, alicyclic, heterocyclic, aromatic amines employing Triton-B/CS₂ system at room temperature (Table 2). This reaction works well with primary alcoholic tosylates in comparison to secondary and tertiary alcoholic tosylates. Steric hindrance could be the reason for lesser yield of secondary or tertiary alcoholic tosylates. It has also been observed that aromatic amines with electron releasing group (EWG) like *p*-anisidine and *p*-toluidine afforded high yields and lesser reaction time as compared to aromatic amine without EWG like aniline. Also, dithiocarbamates of cyclic amines such as cyclohexyl amine was obtained in lesser yields as compared to aliphatic long chain amines. The spectral characterization of all the dithiocarbamates obtained from various amines and alcoholic tosylates were confirmed through the data of authentic dithiocarbamates prepared in our Laboratory from various starting materials.^{37f, 38b, 38d}



Scheme 1: Synthesis of dithiocarbamates

3. Conclusions

We have developed a convenient and efficient protocol for one-pot, solvent-free coupling of various primary and secondary substituted aliphatic, aromatic, alicyclic, heterocyclic amines with a variety of primary, secondary and tertiary alcoholic tosylates employing Triton-B/CS₂ system. This method generates the corresponding dithiocarbamates in good to excellent yields. Furthermore, this method exhibits substrate versatility, mild reaction conditions and experimental convenience. This synthetic protocol developed in our laboratory is believed to offer a more general method for the formation of carbon-oxygen bonds essential to numerous organic syntheses.

4. Experimental

Table 2: Conversion of alcoholic tosylates into dithiocarbamates of general formula **I**.

Comp. No.	R ₁	R ₂	R ₃	R ₄	R ₅	Time (hrs)	Yield	Refs.
1.	2-Naphthyloxypropyl	H	H	<i>n</i> -C ₄ H ₉	H	1	96	38d
2.	2-Naphthyloxyethyl	H	H	<i>c</i> -C ₆ H ₁₃	H	1.5	89	38d
3.	2-Naphthyloxyethyl	H	H	R ₄ = R ₅ = Morpholine		1.5	88	38d
4.	2-Naphthyloxyethyl	H	H	R ₄ = R ₅ = Pyrrolidine		1.5	86	38b
5.	2-Naphthyloxyethyl	H	H	<i>n</i> -C ₃ H ₇	<i>n</i> -C ₃ H ₇	2	85	38b
6.	<i>n</i> -C ₃ H ₇	H	H	<i>n</i> -C ₈ H ₁₇	H	1.5	87	38d
7.	(CH ₃) ₂ CHCH ₂	H	H	<i>n</i> -C ₈ H ₁₇	H	1.5	90	38d
8.	CH ₃ (CH ₂) ₃	H	H	<i>n</i> -C ₄ H ₉	H	1.5	92	38d
9.	CH ₃ (CH ₂) ₄	H	H	<i>c</i> -C ₆ H ₁₁	H	2	88	38d
10.	CH ₃ (CH ₂) ₅	H	H	PhCH ₂	H	1.5	90	37f
11.	CH ₃ (CH ₂) ₆	H	H	4-MePh	H	1.5	92	38d
12.	CH ₃ (CH ₂) ₈	H	H	<i>n</i> -C ₆ H ₁₃	H	1	98	38d
13.	PhCH ₂	H	H	<i>n</i> -C ₄ H ₉	H	1.5	91	38d
14.	PhCH ₂ .CH ₂	H	H	<i>n</i> -C ₆ H ₁₃	H	1.5	94	38d
15.	PhCH ₂	H	H	<i>i</i> -C ₃ H ₇	<i>i</i> -C ₃ H ₇	1.5	89	38d
16.	2-Naphthyloxyethyl	H	H	4-MeOPh	H	1.5	88	38d
17.	<i>n</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉	H	<i>n</i> -C ₈ H ₁₇	H	1.5	84	38d
18.	<i>n</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉	<i>n</i> -C ₁₂ H ₂₅	H	1.5	94	38d
19.	<i>n</i> -C ₆ H ₁₁	H	H	Ph	Br	1.5	82	37f
20.	<i>n</i> -C ₅ H ₁₁	H	H	Cyclohexyl	H	1.5	83	38b
21.	<i>n</i> -C ₄ H ₉	H	H	PhCH ₂ CH ₂	H	1.5	89	38b
22.	<i>n</i> -C ₅ H ₁₁	H	H	Ph.CH ₂ .CH ₂ .CH ₂	H	1.5	92	38b

Chemicals were procured from Merck, Aldrich, and Fluka chemical companies. Reactions were carried out under an atmosphere of Argon. Infra-Red (IR) spectra 4000-200 cm^{-1} were recorded on Bomem MB-104-FTIR spectrophotometer using neat technique, whereas NMRs were scanned on AC-300F, NMR (300 MHz), instrument using CDCl_3 and some other deuterated solvents and TMS as internal standard. Elemental analysis were conducted by means of a Carlo-Erba EA 1110-CNNO-S analyser and agreed favourably with calculated values.

4.1 Typical experimental procedure for the synthesis of dithiocarbamates

An equimolar amount (6 mmol) of Triton-B and CS_2 was and was allowed to stir 20 min at room temperature. Amine (5 mmol) was added and the reaction was continued at rt for 1 h. Now corresponding alcoholic tosylate (2 mmol) compound was added. The reaction was further continued until completion (Table 2). The reaction mixture was poured into 50 cm^3 distilled H_2O and extracted with ethyl acetate thrice. The organic layer was separated, dried (Na_2SO_4), and concentrated to get the desired compound.

4.2 Data of selected compounds:

[4 - (2 - N a p h t h y l o x y) b u t - 1 - y l] n-butyl dithiocarbamate (1): (Table 2, entry 1)^{38b} M.p.106°C. IR (KBr): $\nu = 670$ (C-S), 1114 (C=S), 1474 (Ar), 1510 (Ar), 1609 (Ar), 2874 (CH), 2937(CH), 3418 (NH) cm^{-1} ; ^1H NMR (CDCl_3): $\delta = 0.93$ – 0.97 (t, CH_3), 1.30–1.34 (m, CH_2CH_3), 1.53–1.56 (m, $\text{CH}_2\text{CH}_2\text{CH}_3$), 1.70–1.72 (m, naphthyl-O- CH_2CH_2), 1.95–1.98 (m, S- CH_2CH_2), 2.0 (br, NH), 2.63–2.66 (m, NHCH_2), 2.84–2.88 (t, CH_2 -S-C=S), 4.01–4.04 (t, CH_2 -O-naphthyl), 6.97–7.64 (m, Ar-H) ppm. MS: $m/z = 347$.

3 - (2 - N a p h t h y l o x y) p r o p - 1 - y l] n-hexyl dithiocarbamate (2): (Table 2, entry 2)^{38b} M.p.129°C; IR (KBr): $\nu = 664$ (C-S), 1116 (C=S), 1474 (Ar), 1512 (Ar), 1601 (Ar), 2874

(CH), 2937 (CH), 3395 (NH) cm^{-1} ; ^1H NMR (CDCl_3): $\delta = 0.92$ – 0.96 (t, CH_3), 1.27–1.29 (m, $\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_3$), 1.30–1.34 (m, CH_2CH_3), 1.53–1.56 (m, $\text{CH}_2\text{CH}_2\text{CH}_3$), 2.2 (br, NH), 2.36–2.40 (m, naphthyl-O- $\text{CH}_2\text{CH}_2\text{CH}_2$ -), 2.63–2.66 (m, NHCH_2), 2.83–2.87 (t, CH_2 -S-C=S), 4.01–4.04 (t, CH_2 -O-naphthyl), 6.97–7.64 (m, Ar-H) ppm. MS: $m/z = 361$.

Acknowledgements

Author is thankful to Pro-Vice Chancellor and Dean, Research (Science and Technology), Amity University Uttar Pradesh (AUUP), Lucknow Campus, Lucknow, U. P., for their constant encouragement and support for research. Financial support from the Department of Science and Technology (DST), Govt. of India (Grant No.SR/FT/CS-147/2010) is gratefully acknowledged. The authors confirm that there is no conflict of interest with the commercial identities used inside the manuscript.

References

- (a) C. Lambert, *J. Sulphur Chem.* **2004**, 25, 39-62; (b) G. Eng, X. Song, Q. Duong, D. Strickman, J. Glass, L. May, *Appl. Organomet. Chem.* **2003**, 17, 218-225; (c) S. Senkbeil, J. P. Lafleur, T. G. Jensen, J. P. Kutter, *Min. System Chem. Life Sci.* **2012**, 1423-1425.
- (a) S. L. Cao, Y. P. Feng, Y. Y. Jiang, S. Y. Liu, G. Y. Ding, R. T. Li, *Bioorg. Med. Chem. Lett.* **2005**, 15, 1915-1917; (b) S. L. Cao, Y. Wang, L. Zhu, J. Liao, Y. W. Guo, L. L. Chen, H. Q. Liu, X. Xu, *Eur. J. Med. Chem.* **2010**, 45, 3850-3857; (c) S. L. Cao, Y. Han, C. Z. Yuan, Y. Wang, Z. K. Xiahou, J. Liao, R. T. Gao, B. B. Mao, B. L. Zhao, Z. F. Li, X. Xu, *Eur. J. Med. Chem.* **2013**, 64, 401-409; (d) B. Cvek, Z. Dvorak, *Curr. Pharm. Design.* **2007**, 13, 3155-3167; (e) O. Guzel, A. Salman, *Bioorg. Med. Chem.* **2006**, 14, 7804-7815; (f) Y. Qian, G. Y. Ma, Y. Yang, K. Cheng, Q. Z. Zheng, W. J. Mao, L. Shi, J. Zhao, H. L. Zhu, *Bioorg. Med. Chem.* **2010**, 18, 4310-4316.
- W. D. Rudolf, *J. Sulfur Chem.* **2007**, 28, 295-339; (b) A. R. Katrizky, S. Singh, P. P. Mahapatra, N. Clemense, K. Kirichenko, *ARKIVOC*, IX, **2005**, 63-79.
- T. W. Greene, P. G. M. Wuts, *Protecting Groups in Organic Synthesis* 3rd Edition, **1999**, 484.
- L. Gomez, A. Wagner, C. Mioskowski, *J. Comb. Chem.* **2000**, 2, 75-79.
- D. Crich, L. Quintero, *Chem. Rev.* **1989**, 89, 1413-1432.

7. D. Zhang, J. Chen, Y. Liang, H. Zhou, *Synth. Commun.* **2005**, 35, 521-526.
8. N. Alexander, K. Ramalingam, C. Rizzoli, *Inorg. Chim. Acta.* **2011**, 365, 480-483.
9. (a) M. A. Haendel, F. Tilton, G. S. Bailey, R. L. Tanguay, *Toxicol. Sci.* **2004**, 81, 390-400; (b) S. Senkbeil, J. P. Lafleur, T. G. Jensen, J. P. Kutter, *Min. System Chem. Life Sci.* **2012**, 1423-1425.
10. I. Rogachev, V. Kampel, V. Gusis, N. Cohen, J. Gressel, A. Warshawsky, *Pesticide Biochem & Physiol.* **1989**, 60, 133-145.
11. G. Eng, X. Song, Q. Duong, D. Strickman, J. Glass, L. May, *Appl. Organomet. Chem.* **2003**, 17, 218-225.
12. C. Lambert, *J. Sulphur Chem.* **2004**, 25, 39-62.
13. S. T. Byrne, P. Gu, J. Zhou, S. M. Denkin, C. Chong, D. Sullivan, J. O. Liu, Y. Zhang, *Mycobacterium tuberculosis. Antimicrob. Agents Chemother.* **2007**, 51, 124495-124497.
14. Y. C. [Zheng](#), Y. C. [Duan](#), J. L. [Ma](#), R. M. [Xu](#), X. [Zi](#), W. L. [Lv](#), M. M. [Wang](#), X. M. [Ye](#), S. [Zhu](#), D. [Mobley](#), Y. Y. [Zhu](#), J. W. [Wang](#), J. F. [Li](#), Z. R. [Wang](#), W. [Zhao](#), H. M. [Liu](#), *J. Med. Chem.* **2013**, 56, 8543-8560.
15. J. Coro, R. Atherton, S. Little, H. Wharton, V. Yardley, A. Alvarez, M. Suarez, R. Perez, H. Rodriguez, *Bioorg. Med. Chem.* **2006**, 16, 1312-1315.
16. V. Marakov, O. B. Riabova, A. Yuschenko, N. Urlyapova, A. Daudova, P. F. Ziplef, U. Mollmann, *J. Antimicrobial Chemother.* **2006**, 57, 1134-1138.
17. O. Guzel, A. Salman, *Bioorg. Med. Chem.* **2006**, 14, 7804-7815.
18. Y. Zou, S. Yu, R. Li, Q. Zhao, X. Li, M. Wu, T. Huang, X. Chai, H. Hu, Q. Wu, *Eur. J. Med. Chem.* **2014**, 74, 366-374.
19. U. A. Mohsen, *Cukurova Med. J.* **2014**, 39, 729-735.
20. S. Jangir, V. Bala, N. Lal, L. Kumar, A. Sarswat, A. Kumar, Hamidullah, K. S. Saini, V. Sharma, V. Verma, J. P. Maikhuri, R. Konwar, G. Gupta, V. L. Sharma, *European J. Med. Chem.* **2014**, 85, 638-647.
21. K. Chauhan, M. Sharma, P. Singh, V. Kumar, P. K. Shukla, M. I. Siddiqi, P. M. S. Chauhan, *Med. Chem. Comm.* **2012**, 3, 1104-1110.
22. P. Liu, C. Li, J. Zhang, X. Xu, *Synth. Commun.* **2013**, 43, 3342-3351.
23. A. Z. Halimjani, Y. Pourshojaei, M. R. Saidi, *Tetrahedron Lett.* **2009**, 50, 32-34.
24. J. Jamir, U. B. Sinha, J. Nath, B. K. Patel, *Synth. Commun.* **2012**, 42, 951-958.
25. M. Kienle, A. Unsinn, P. Knochel, *Angew. Chem. Int. Ed.* **2010**, 49, 4751-4754.
26. V. Aucagne, C. Lorin, A. Tatibouet, P. Rollin, *Tetrahedron Lett.* **2005**, 46, 4349-4352.
27. N. K. Kumar, K. Sreeramamurthy, S. Palle, K. Mukkanti, P. Das, *Tetrahedron Lett.* **2010**, 51, 899-902.
28. M. A. Khalizadeh, Z. Hossaini, M. A. Baradarani, A. Hassania, *Tetrahedron Lett.* **2010**, 66, 8464-8467.
29. U. A. Mohsin, *Curkova Med. J.* **2014**, 39, 729-735.
30. S. K. Tandel, S. Rajappa, S. V. Pansare, *Tetrahedron* **1993**, 49, 7479-7486.
31. F. R. Charati, Z. Hossaini, R. Hajinasiri, *J. Applied Chem. Res.* **2012**, 20, 54-59.
32. L. J. Bahrin, P. J. Jones, H. Hopf, *Beilstein J. Org. Chem.* **2012**, 8, 1999-2003.
33. J. T. R. Burke, B. S. Bajwa, A. E. Jacobsen, K. C. Rice, R. A. Streaty, W. Klee, *J. Med. Chem.* **1984**, 27, 1570-1574.
34. W. Walter, K. D. Bode, *Angew. Chem. Int. Ed.* **1967**, 6, 281-293.
35. J. Garin, E. Melandz, F. L. Merchain, T. Tejero, S. Urid, J. Ajaysteron, *Synthesis* **1991**, 147-149.
36. (a) S. Sharma, *Synthesis*. **1978**, 11, 803-820; (b) R. M. Pascual, *Synlett* **2015**, 26, 1776-1777.
37. (a) D. Chaturvedi, A. Kumar, S. Ray, *Synth. Commun.* **2002**, 32, 2651-2656; (b) D. Chaturvedi, A. Kumar, S. Ray, *Tetrahedron Lett.* **2003**, 44, 7637-7639; (c) D. Chaturvedi, S. Ray, *Lett. Org. Chem.* **2005**, 2, 742-744; (d) D. Chaturvedi, S. Ray, *J. Sulfur Chem.* **2005**, 26, 365-371; (e) D. Chaturvedi, S. Ray, *J. Sulfur Chem.* **2006**, 27, 265-270; (f) D. Chaturvedi, S. Ray, *Tetrahedron Lett.* **2006**, 47, 1307-1309; (g) D. Chaturvedi, N. Mishra, V. Mishra, *Chin. Chem. Lett.* **2006**, 17, 1309-1312; (h) D. Chaturvedi, S. Ray, *Tetrahedron Lett.* **2007**, 48, 149-151; (i) D. Chaturvedi, N. Mishra, V. Mishra, *Tetrahedron Lett.* **2007**, 48, 5043-5045; (j) D. Chaturvedi, N. Mishra, V. Mishra, *Synthesis* **2008**, 355-357; (k) D. Chaturvedi, A. K. Chaturvedi, N. Mishra, V. Mishra, *Tetrahedron Lett.* **2008**, 49, 4886-4888; (l) D. Chaturvedi, A. K. Chaturvedi, N. Mishra, V. Mishra, *J. Iran. Chem. Soc.* **2009**, 6, 510-513; (m) D. Chaturvedi, N. Mishra, A. K. Chaturvedi, V. Mishra, *Phosphorus Sulfur Silicon* **2009**, 184, 550-558; (n) A. K. Chaturvedi, D. Chaturvedi, N. Mishra, V. Mishra, *J. Iran. Chem. Soc.* **2010**, 7, 702-706; (o) A. K. Chaturvedi, D. Chaturvedi, N. Mishra, V. Mishra, *J. Iran. Chem. Soc.* **2011**, 8, 396-400; (p) D. Chaturvedi, S. Zaidi, A. K. Chaturvedi, S. Vaid, A. K. Saxena, *Ind. J. Chem.* **2016**, 55, 1019-1025.
38. (a) D. Chaturvedi, S. Ray, *Monatsh. Chem.* **2006**, 137, 201-206; (b) D. Chaturvedi, S. Ray, *Monatsh. Chem.* **2006**, 137, 311-317; (c) D. Chaturvedi, S. Ray, *Monatsh. Chem.* **2006**, 137, 459-463; (d) D. Chaturvedi, S. Ray, *Monatsh. Chem.* **2006**, 137, 465-469; (e) D. Chaturvedi, A. K. Chaturvedi, N. Mishra, V. Mishra, *Synth. Commun.* **2008**, 38, 4013-4022; (f) D. Chaturvedi, N. Mishra, A. K. Chaturvedi, V. Mishra, *Synth. Commun.* **2009**, 39, 1273-1281.
39. G. W. Kabalka, M. Varma, R. S. Varma, P. C. Srivastava, F. F. Knapp, *J. Org. Chem.* **1986**, 51, 2386-2388.