Monatsh Chem 139, 1463–1466 (2008)
DOI 10.1007/s00706-008-0955-8
Printed in The Netherlands

Monatshefte für Chemie
Chemical Monthly

Triton-B catalyzed, efficient one-pot synthesis of carbazates

Devdutt Chaturvedi[1], Amit K. Chaturvedi[2], Nisha Mishra[2], Virendra Mishra[2]

[1] Bio-Organic Chemistry Division, Indian Institute of Integrative Medicine, Jammu-Tawi, J&K, India
[2] Synthetic Research Laboratory, Department of Chemistry, B.S.A.P.G. College, Mathura, U.P., India

Received 11 April 2008; Accepted 4 May 2008; Published online 31 July 2008

Abstract A quick and efficient, one-pot synthesis of carbazates was accomplished in high yields by the reaction of various primary, secondary, and tertiary alkyl halides with a variety of substituted hydrazines using the benzyltrimethylammonium hydroxide (Triton-B)/CO_2 system. The reaction conditions are mild with simpler work-up procedures than the reported methods.

Keywords Alkyl halides; Benzyltrimethylammonium hydroxide; Carbon dioxide; Substituted hydrazines; Carbazates.

Introduction

Organic carbazates have attracted much attention due to their numerous remarkable medicinal, industrial, and synthesis applications [1, 2]. They have extensively been used as pharmaceuticals [3], agrochemicals [4], intermediates in organic synthesis [5], for protection of amino groups in peptide synthesis [6], as linkers in solid phase organic synthesis [7], and as donor ligands in complexation reactions with transition metals [8]. To satisfy their demand, their synthesis has been changed from the use of costly and toxic chemicals like phosgene [9] and its derivatives [10] directly or indirectly, to the abundantly available cheap and safe reagents like CO_2. However, their formation using CO_2 employed harsh reaction conditions, such as use of strong bases, high reaction temperatures, and long reaction times [11]. Thus, we were prompted to embark on the improved procedures. Our group [12] has been engaged during the past several years in the development of new methodologies for the preparation of carbamates, dithiocarbamates, and related compounds using cheap, abundantly available, and safe reagents like CO_2 and CS_2. Recently [13], we have found that benzyltrimethylammonium hydroxide (Triton-B) is the best catalyst for the synthesis of carbamates, dithiocarbamates, and dithiocarbonates (xanthates). We report here an efficient, one-pot synthesis of carbazates from a variety of primary, secondary, and tertiary alkyl halides and substituted hydrazines using the Triton-B/CO_2 system.

Correspondence: Devdutt Chaturvedi, Bio-Organic Chemistry Division, Indian Institute of Integrative Medicine, Canal Road, Jammu-Tawi 18000, J&K, India. E-mail: ddchaturvedi002@yahoo.co.in

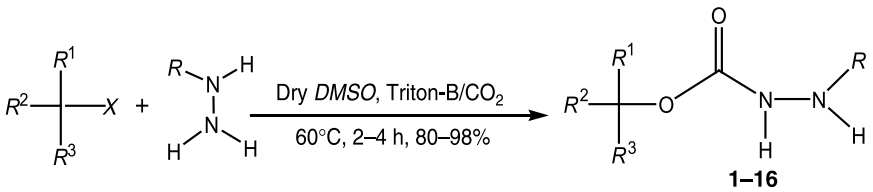
Results and discussion

Substituted hydrazine was taken in dry *DMSO* and purified CO_2 gas was bubbled in it at 60°C for 30 min with constant stirring. Now, Triton-B was slowly added with constant stirring. The reaction was continued for another 30 min, and then the corresponding alkyl halide was added. The reaction was further continued until completion as checked by TLC (see Table 1). It is proposed that the O^- of the carbazate ion produced will attack the electrophilic carbon of the respective alkyl halide to afford carbazates in high yields (80–98%) at room temperature in 3–5 h, as mentioned in Table 1. The reaction proved to be successful and the desired products

Table 1 Conversion of alkyl halides into carbazates **1–16**[a]

Product	R^1	R^2	R^3	X	R	Time/h	Yields/%[b]
1	n-C_3H_7	H	H	Br	4-*Me*O-*Ph*	3	94
2	*Ph*CH_2CH_2	H	H	Br	*Ph*	3	96
3	*Ph*CH_2	H	H	Cl	*Ph*	4	87
4	*Ph*	H	H	Cl	*Bn*	4.5	92
5	C_2H_5	*Me*	H	Br	*Bn*	4.5	90
6	*Ph*-4-*Me*O	H	H	Cl	*Ph*-3-NO_2	4.5	85
7	C_3H_7	H	H	Br	*Ph*-4-NO_2	4.5	85
8	C_3H_7	H	H	Br	*Ph*-2,4-NO_2	5	80
9	C_3H_7	H	H	Br	Naphthyl	4.5	83
10	C_4H_9	C_4H_9	H	Br	*Ph*	4.5	89
11	C_4H_9	C_4H_9	C_4H_9	Br	*Ph*	4.5	88
12	C_5H_{11}	H	H	Cl	n-C_4H_9	3	96
13	C_7H_{15}	H	H	Cl	*Ph*	3	96
14	C_9H_{19}	H	H	Cl	n-C_4H_9	3	98
15	C_3H_7	C_3H_7	H	Br	*Ph*	4.5	86
16	*Ph*	CH_3	H	Br	*Ph*	5	82

[a] All the products were characterized by IR, NMR, and mass spectroscopic data
[b] Isolated yields



Scheme 1

were isolated and their structures confirmed by various spectroscopic and analytical techniques. Thus, various substituted hydrazines were reacted with a variety of primary, secondary, and tertiary alkyl halides using the Triton-B/CO_2 system to afford the corresponding carbazates in good to excellent yields (Table 1) with the reaction conditions as shown in Scheme 1.

We tried several solvents like *n*-heptane, *n*-hexane, acetonitrile, benzene, toluene, methanol, dichloromethane, chloroform, *DMSO*, dimethylformamide, and hexamethylphosphoric triamide of which dry *DMSO* proved to be the most suitable one at room temperature.

In conclusion, we developed a convenient and efficient protocol for the one-pot, three-component coupling of various substituted hydrazines with a variety of primary, secondary, and tertiary alkyl halides *via* a CO_2 bridge using Triton-B. This method generates the corresponding carbazates in good to excellent yields. Furthermore, this method exhibits substrate versatility, mild reaction conditions, and experimental convenience. This synthesis protocol developed is believed to offer a more general method for the formation of carbon–oxygen bonds essential to numerous organic syntheses.

Experimental

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

Typical experimental procedure

To a stirred solution (under Ar) of 3 mmol substituted hydrazine in 5 cm^3 anhyd. *DMSO* carbon dioxide was continuously bubbled and 2 cm^3 Triton-B were added at 60°C. Then the mixture was stirred for 0.5 h at which point 3 cm^3 of the required alkyl halide were added over a period of 5 min. The stirring was further continued until the completion of

reaction (*cf.* Table 1). The reaction mixture was poured into 20 cm^3 water and the organic layer was extracted with $3 \times 10\,cm^3$ *EtOAc*. The organic layer was washed with 20 cm^3 0.1 *N* HCl, 25 cm^3 saturated $NaHCO_3$ solution, 30 cm^3 brine, and then dried (Na_2SO_4) and concentrated to get the desired compound.

N′-(4-Methoxyphenyl)hydrazine carboxylic acid butyl ester (**1**, $C_{12}H_{18}N_2O_3$)
Oil; IR (neat): $\bar{\nu} = 1680\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.96$ (t, 3H, $J = 7.3$ Hz), 1.34 (m, 2H), 1.86 (m, 2H), 3.73 (s, 3H), 4.12 (t, $J = 6.5$ Hz, 2H), 4.85 (m, NH), 6.74–7.66 (m, 4H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.7$, 19.5, 32.5, 63.5, 112.5, 114.9, 134.5, 152.4, 160.6 (C=O) ppm; MS (EI): $m/z = 238$.

N′-Phenylhydrazine carboxylic acid 3-phenyl propyl ester (**2**, $C_{16}H_{18}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1685\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 1.92$ (m, 2H), 2.56 (t, 2H, $J = 7.2$ Hz, -*PhCH*$_2$), 4.10 (t, $J = 6.5$ Hz, 2H), 4.67 (br, N*HPh*), 6.66–7.12 (m, 10H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 32.4$, 34.4, 63.5, 112.6, 119.4, 125.7, 128.8, 129.6, 138.7, 161 (C=O) ppm; MS: $m/z = 270$.

N′-Phenylhydrazine carboxylic acid phenethyl ester (**3**, $C_{15}H_{16}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1681\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 2.83$ (2H, t, $J = 6.7$ Hz, Ph*CH*$_2$CH$_2$O), 4.42 (t, 2H, $J = 7.2$ Hz, *PhCH*$_2$O), 4.77 (br, H, *PhNH*), 6.69–7.15 (m, 10H, *Ar*–H), 8.05 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 35.5$, 65.9, 112.3, 118.6, 128.5, 129.5, 140.3, 142.5, 165.4 (C=O) ppm; MS: $m/z = 256$.

N′-Butylhydrazine carboxylic acid benzyl ester (**4**, $C_{12}H_{18}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1680\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.99$ (t, $J = 7.2$ Hz, 3H, CH_3), 1.34 (m, 2H, *CH*$_2$CH$_3$), 1.56 (m, 2H, *CH*$_2$CH$_2$CH$_3$), 2.15 (br, NH), 2.66 (m, 2H, NH*CH*$_2$), 5.13 (s, 2H, *PhCH*$_2$), 7.10–7.19 (m, 5H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.8$, 20.3, 31.6, 51.2, 69.3, 126.8, 127.6, 128.5, 141.8, 158 (C=O) ppm; MS: $m/z = 222$.

N′-Butylhydrazine carboxylic acid sec-butyl ester (**5**, $C_9H_{20}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1681\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.98$ (t, $J = 7.2$ Hz, 3H, CH_3), 1.15 (t, $J = 7.0$ Hz, 3H, CH_3), 1.38 (m, 2H, CH$_2$*CH*$_3$), 1.42 (d, $J = 6.5$ Hz, 3H, CH*CH*$_3$), 1.56 (m, 2H, CH$_3$CH$_2$*CH*$_2$), 2.0 (br, NH), 2.66 (m, 2H, NH*CH*$_2$), 4.20 (m, C*H*CH$_3$), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 8.2$, 13.8, 19.2, 20.5, 29.3, 71.4, 156.9 (C=O) ppm; MS: $m/z = 188$.

N′-(3-Nitrophenyl)hydrazine carboxylic acid 4-methoxybenzyl ester (**6**, $C_{15}H_{15}N_3O_5$)
Oil; IR (neat): $\bar{\nu} = 1682\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 3.73$ (s, 3H, O*CH*$_3$), 4.05 (br, H, *NHPhOMe*), 5.34 (s, 2H), 6.66–7.69 (m, 8H, *Ar*–H), 8.1 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 69.3$, 107.6, 114.8, 118.8, 128.5, 129.9, 133.6, 143.6, 148.7, 160.6 (C=O) ppm; MS: $m/z = 317$.

N′-(4-Nitrophenyl)hydrazine carboxylic acid butyl ester (**7**, $C_{11}H_{15}N_3O_4$)
Oil; IR (neat): $\bar{\nu} = 1682\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.99$ (t, $J = 7.2$ Hz, 3H, CH_3), 1.36 (m, 2H, *CH*$_2$CH$_3$), 1.57 (m, 2H, OCH$_2$*CH*$_2$), 4.04 (br, *NH*ArNO$_2$), 6.92–8.15 (m, 4H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.8$, 21.7, 32.3, 63.7, 113.5, 124.6, 138.8, 143.3, 159 (C=O) ppm; MS: $m/z = 253$.

N′-(2,4-Dinitrophenyl)hydrazine carboxylic acid butyl ester (**8**, $C_{11}H_{14}N_4O_6$)
Oil; IR (neat): $\bar{\nu} = 1681\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.98$ (t, $J = 7.2$ Hz, 3H, CH_3), 1.36 (m, 2H, *CH*$_2$CH$_3$), 1.59 (m, 2H, SCH$_2$*CH*$_2$), 4.08 (br, *NH*ArNO$_2$), 7.19–9.50 (m, 3H, *Ar*–H), 8.10 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.8$, 19.3, 31.8, 63.8, 113.6, 119.2, 130.2, 132.8, 139.7, 143.3, 160 (C=O) ppm; MS: $m/z = 298$.

N′-Naphth-2-ylhydrazine carboxylic acid butyl ester (**9**, $C_{15}H_{18}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1681\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.96$ (t, $J = 7.2$ Hz, 3H, CH_3), 1.36 (m, 2H, *CH*$_2$CH$_3$), 1.57 (m, 2H, OCH$_2$*CH*$_2$), 4.05 (br, H, Ar–N*H*), 4.12 (t, $J = 7.0$ Hz, 2H), 6.76–7.55 (m, 7H, *Ar*–H), 8.02 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.9$, 22.1, 32.5, 33.9, 107.4, 117.2, 121.3, 124.5, 126.6, 127.2, 133.5, 142.6, 161 (C=O) ppm; MS: $m/z = 258$.

N′-Phenylhydrazine carboxylic acid 1-butylpentyl ester (**10**, $C_{16}H_{26}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1682\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.99$ (t, $J = 7.2$ Hz, 6H, CH_3), 1.33 (m, 4H, *CH*$_2$CH$_2$CH), 1.38 (m, 4H, *CH*$_2$CH$_3$), 1.54 (m, 4H, CH*CH*$_2$), 3.95 (t, O*CH*), 4.15 (br, *NH*Ar), 6.66–7.18 (m, 5H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 14.3$, 23.1, 28.5, 36.2, 72.7, 112.2, 119.3, 129.0, 142.4, 158 (C=O) ppm; MS: $m/z = 278$.

N′-Phenylhydrazine carboxylic acid 1,1-dibutylpentyl ester (**11**, $C_{20}H_{34}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1684\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.96$ (t, $J = 7.2$ Hz, 9H, CH_3), 1.29 (m, 4H, *CH*$_2$CH$_2$C), 1.33 (m, 4H, *CH*$_2$CH$_3$), 1.50 (m, 4H, CH*CH*$_2$), 4.0 (br, H, *NH*–Ar), 6.67–7.19 (m, 5H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 14.3$, 23.5, 26.8, 39.8, 72.4, 112.5, 119.3, 129.6, 142.2, 162 (C=O) ppm; MS: $m/z = 334$.

N′-Butylhydrazine carboxylic acid hexyl ester (**12**, $C_{11}H_{24}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1684\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.98$ (t, $J = 7.0$ Hz, 6H, CH_3), 1.30 (m, 4H, *CH*$_2$*CH*$_2$CH$_2$CH$_3$), 1.36 (t, $J = 7.0$ Hz, 2H, *CH*$_2$CH$_3$), 1.58 (m, 2H, NHCH$_2$*CH*$_2$), 1.63 (t, $J = 6.5$ Hz, 2H, *CH*$_2$N), 2.0 (br, 2H, NH), 2.66 (t, 2H, NH*CH*$_2$), 4.10 (t, 2H, $J = 7.2$ Hz, O*CH*$_2$), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.7$, 14.1, 20.2, 23.1, 28.6, 31.5, 32.6, 69.5, 164.5 (C=O) ppm; MS: $m/z = 216$.

N′-Phenylhydrazine carboxylic acid n-octyl ester
(**13**, $C_{15}H_{24}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1685\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.96$ (t, $J = 7.2\,Hz$, 3H, CH_3), 1.30 (m, 8H, CH_2), 1.35 (m, 2H, CH_2CH_3), 1.63 (m, 2H, OCH_2CH_2), 4.0 (br, Ph*NH*), 4.12 (t, 2H, $J = 7.0\,Hz$, OCH_2), 6.66–7.25 (m, 5H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 14.5$, 23.10, 27.5, 30.5, 32.5, 63.6, 112.2, 129.6, 118.9, 142.2, 163 (C=O) ppm; MS: $m/z = 264$.

N′-Butylhydrazine carboxylic acid decyl ester
(**14**, $C_{15}H_{32}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1683\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.97$ (s, 3H, CH_3), 0.99 (s, 3H, CH_3), 1.29 (m, 12H, CH_2), 1.34 (m, 4H, CH_2CH_3), 1.57 (m, 2H, $CH_2CH_2CH_3$), 2.0 (br, NH), 2.65 (m, 2H, $NHCH_2$), 4.12 (t, $J = 7.0\,Hz$, 2H, OCH_2), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 13.7$, 14.5, 20.3, 23.1, 28.9, 30.6, 30.9, 31.5, 32.5, 63.5, 160 (C=O) ppm; MS: $m/z = 272$.

N′-Phenylhydrazine carboxylic acid 1-propylbutyl ester
(**15**, $C_{14}H_{22}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1680\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 0.97$ (s, 3H, CH_3), 1.33 (m, 4H, CH_2CH_3), 1.54 (m, 4H, $CHCH_2$), 3.95 (m, H, C*H*–O), 4.1 (br, H, NH–*Ar*), 6.66–7.22 (m, 5H, *Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 14.5$, 20.1, 38.4, 72.8, 112.5, 118.3, 129.6, 143.3, 160 (C=O) ppm; MS: $m/z = 250$.

N′-Phenylhydrazine carboxylic acid 1-phenyl ethyl ester
(**16**, $C_{15}H_{16}N_2O_2$)
Oil; IR (neat): $\bar{\nu} = 1682\,cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta =$ 1.69 (d, $J = 7.2\,Hz$, 3H, CH_3), 4.2 (br, NH–Ph), 5.42 (m, *CH*–O), 6.66–7.22 (m, 10*Ar*–H), 8.0 (br, NH) ppm; ^{13}C NMR ($CDCl_3$): $\delta = 23.4$, 74.2, 112.5, 118.9, 126.5, 128.5, 129.7, 141.3, 142.5, 163.5 (C=O) ppm; MS: $m/z = 256$.

Acknowledgements

Authors wish to thank SIAF division of CDRI for providing spectroscopic and analytical data.

References

1. Ragnarsson U (2001) Chem Soc Rev 30:205
2. Schmidt EU (2001) Hydrazine and its derivatives preparation, properties, applications, 2nd edn. Wiley-interscience, New York
3. a) Pedras MSC, Jha M (2006) Bioorg Med Chem 14:4958; b) Shailendra, Bharti N, Naqvi F, Azam A (2002) Helv Chim Acta 85:2713; c) Bharti N, Maurya MR, Naqvi F, Azam A (2000) Bioorg Med Chem Lett 10:2243; d) Bharti N, Mannar MR, Fehmida N, Bhattacharya A, Bhattacharya S, Azam A (2000) Eur J Med Chem 35:481
4. a) Sengupta SK, Pandey OP, Rao GP (1999) Sugarcane Pathology 1:279; b) Chen HS, Li ZH, Han YH, Wang ZW (1999) Chin Chem Lett 10:365; c) Chaturvedi K, Jaiswal AK, Mishra KN, Pandey OP, Sengupta SK (1998) ACH-Models Chem 135:93; d) Briggs GC, Cornell CL, Mansfield DJ, Turner RM (1999) PCT Int Appl 1999, WO9923066, CAN: 130:337920
5. a) Connolly TJ, Crittal AJ, Ebrahim AS, Ji G (2000) Org Process Res Dev 4:526; b) Gordan MS, Krause JG, Linneman-Mohr MA, Parchue RR (1980) Synthesis 3:244; c) Hauser MJ (1966) J Org Chem 31:968
6. a) Sakakibara S, Honda I, Naruse M, Kanaoka M (1969) Experimentia 25:576; b) Sakakibara S, Honda I, Takada K, Miyoshi M, Ohnishi T, Okumura K (1969) Bull Chem Soc Jpn 42:809; c) Quibell M, Turnell WG, Johnson T (1993) J Chem Soc Perkin Trans I 22:2843; d) Gray CJ, Quibell M, Baggett N, Hammerle T (1992) Int J Pept Protien Res 40:351
7. a) Huang JY, Choi HS, Lee DH, Yoo SE, Gong YD (2005) J Comb Chem 7:136; b) Hwang JY, Choi HS, Lee DH, Gong YD (2005) J Comb Chem 7:816
8. a) Bolzati C, Benini E, Cavazza-Ceccato M, Cozzala E, Malago E, Agostini S, Tisato F, Rofosco F, Bandoli G (2006) Bioconjugate Chem 17:419; b) Ali MA, Mirza AH, Butcher RJ, Krause KA (2006) Transit Metal Chem 31:79; c) Singh R, Kaushik NK (2004) Main Group Met Chem 27:327
9. Dyker H, Scherkenbeck J, Gondol D, Goehrt A, Harder A (2001) J Org Chem 66:3760
10. a) Dutta AS, Morley JS (1975) J Chem Soc Perkin Trans I 1712; b) Nara S, Sakamoto T, Miyazawa E, Kikugawa Y (2003) Synth Commun 33:87
11. a) Saxena A, Tandon JP (1983) Polyhedron 2:443; b) Fox DL, Ruxer JT, Liver RM, Alford KL, Salvatore RN (2004) Tetrahedron Lett 45:401
12. For Reviews see: a) Chaturvedi D, Ray S (2007) Curr Org Chem 11:987; b) Chaturvedi D, Mishra N, Mishra V (2007) Curr Org Synthesis 3:308; For research work see: c) Chaturvedi D, Kumar A, Ray S (2002) Synth Commun 32:2651; d) Chaturvedi D, Kumar A, Ray S (2003) Tetrahedron Lett 44:7637; e) Chaturvedi D, Ray S (2005) Lett Org Chem 2:742; f) Chaturvedi D, Ray S (2005) J Sulfur Chem 26:365; g) Chaturvedi D, Ray S (2006) J Sulfur Chem 27:265; h) Chaturvedi D, Ray S (2006) Tetrahedron Lett 47:1307; i) Chaturvedi D, Mishra N, Mishra V (2006) Chinese Chem Lett 17:1309; j) Chaturvedi D, Ray S (2007) Tetrahedron Lett 48:149; k) Chaturvedi D, Mishra N, Mishra V (2007) J Sulfur Chem 28:39; l) Chaturvedi D, Mishra N, Mishra V (2007) J Sulfur Chem 28:607; m) Chaturvedi D, Mishra N, Mishra V (2007) Tetrahedron Lett 48:5043; n) Chaturvedi D, Mishra N, Mishra V (2008) Monatsh Chem 139:267; o) Chaturvedi D, Mishra N, Mishra V (2008) Synthesis:355
13. a) Chaturvedi D, Ray S (2006) Monatsh Chem 137:201; b) Chaturvedi D, Ray S (2006) Monatsh Chem 137:311; c) Chaturvedi D, Ray S (2006) Monatsh Chem 137:459; d) Chaturvedi D, Ray S (2006) Monatsh Chem 137:465; e) Chaturvedi D, Ray S (2006) Monatsh Chem 137:1219