HETEROCYCLES, Vol. 80, No. 1, 2010, pp. 593 - 600. © The Japan Institute of Heterocyclic Chemistry
Received, 19th December, 2008, Accepted, 13th April, 2009, Published online, 21st April, 2009
DOI: 10.3987/COM-08-S(S)4

NICKEL – PROMOTED FAVORSKII TYPE REARRANGEMENT OF CYCLIC α-BROMOKETONES

Vishnu K. Tandon,* Anoop K. Awasthi, Kunwar A. Singh, Hardesh K. Maurya, and Sanjay K. Gautam

Department of Chemistry, University of Lucknow, Lucknow – 226 007, India

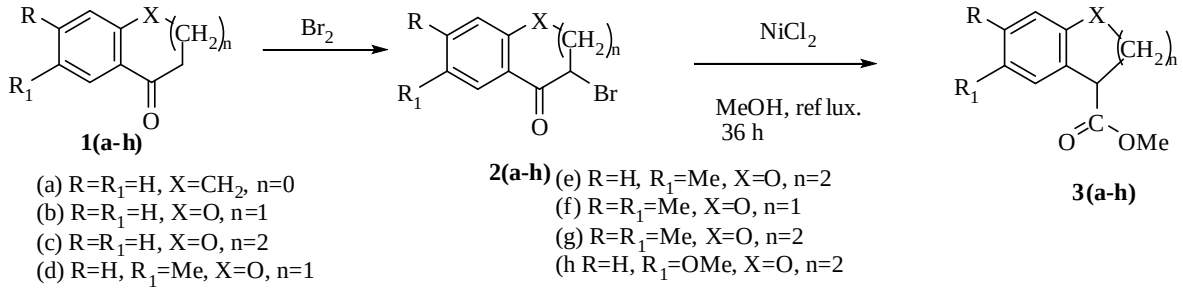
Vishnutandon@yahoo.co.in

Dedicated to Professor Akira Suzuki on occasion of his 80th birthday.

Abstract — Favorskii type rearrangement of cyclic α-bromo ketones **2** is promoted by $NiCl_2$ in refluxing methanol, giving the rearranged carboxylic acid ester **3** in excellent yields. The reaction of 4-bromo-2,3,4,5-tetrahydronaphth [2,1-*b*]oxepin-5-one (**5**) and its regioisomer **8** with $NiCl_2$ in MeOH resulted in Favorskii rearranged carboxylic acid esters **6** and **9** respectively.

The rearrangement of α-haloketones to the carboxylic acids, esters, salts or amides is a powerful method in organic synthesis[1] and is known as Favorskii rearrangement. This reaction, however, is promoted by a strong base such as alkalies alkoxides or amines.[2] Development of this important rearrangement promoted by a catalytic amount of active species has been strongly desired since long time. Favorskii rearrangement in presence of metal hydride and aromatic amines is also reported.[3] DBU in DMSO has been used for Favorskii rearrangement of trichlorothioacetamides.[4] Aq. KCN in presence of α- or β-cyclodextrin was reported to catalyze the reaction of 6,7-dibromo derivative of zerumbone.[5] Lithium aluminium hydride has recently been used to catalyze the rearrangement of tricyclic α-bromoketone.[6] The efficiency of the catalyst used in recent years is generally not very high based on the yields reported in literature. As an extension of our recent investigations on the use of transition metal, alkaline earth metal and Lewis acids in organic synthesis,[7-10] we examined the Favorskii type rearrangement of cyclic α-haloketones **2**. $NiCl_2$ was found to promote the reaction of cyclic α-bromoketone **2** in presence of MeOH as shown in Scheme 1. When cyclic α-bromoketones **2** in methanol were treated with $NiCl_2$ and

the mixture was refluxed for 36 h, rearranged carboxylic acid methyl esters **3** were obtained in excellent yield (Table 1). Analogous reaction of **2** with $CuCl_2$ resulted in formation of **3** albeit in comparatively lesser yields.



1(a-h)

(a) R=R$_1$=H, X=CH$_2$, n=0
(b) R=R$_1$=H, X=O, n=1
(c) R=R$_1$=H, X=O, n=2
(d) R=H, R$_1$=Me, X=O, n=1

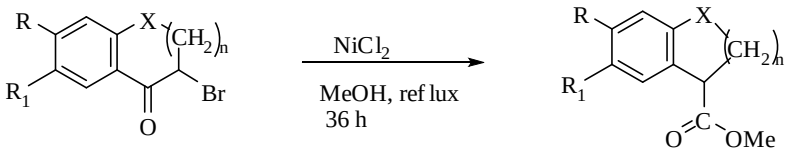
2(a-h) (e) R=H, R$_1$=Me, X=O, n=2
(f) R=R$_1$=Me, X=O, n=1
(g) R=R$_1$=Me, X=O, n=2
(h R=H, R$_1$=OMe, X=O, n=2

3(a-h)

Scheme 1

The $NiCl_2$ promoted Favorskii type rearrangement of several cyclic α-bromoketones **2** is summarized in Table 1. We have compared results using $NiCl_2$ as a promoter, with those by conventional Favorskii rearrangement using NaOMe as a base in MeOH (Table 1) and found that $NiCl_2$ acts as a better promoter for Favorskii type rearrangement. $NiCl_2$ was taken in excess (3 equivalent) because the reactant was not completely converted into the product. Using 1 or 2 equivalent $NiCl_2$, long time (50-60 h) refluxing was required and hence an excess of $NiCl_2$ was required to facilitate the reaction.

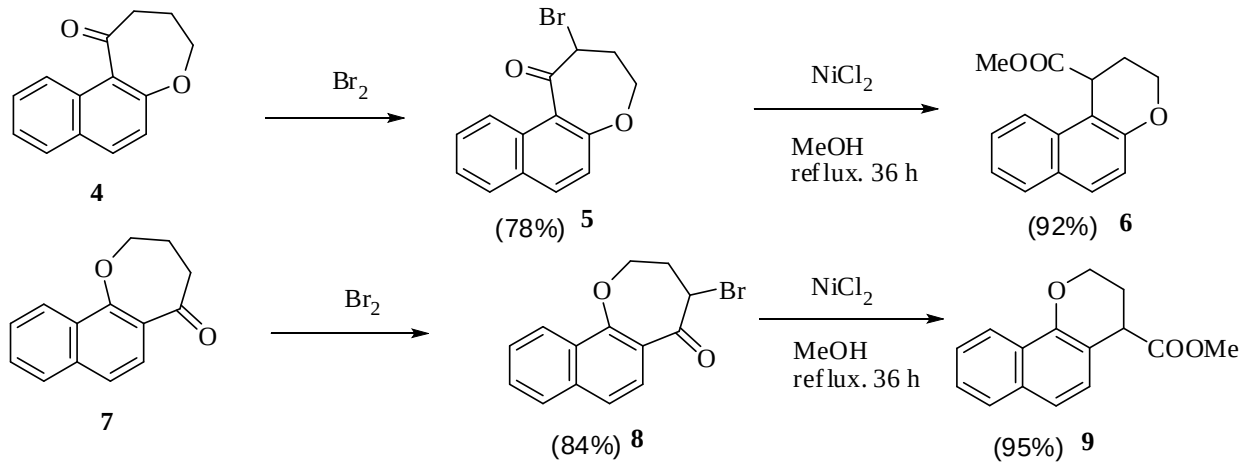
Table 1. Ni-Catalyzed Favorskii type rearrangement of cyclic α-bromoketones **2**



2(a-h) **3(a-h)**

Entry	Compound	R	R_1	X	n	Yields of **2** (%)	Yields of **3** (%) in $NiCl_2$/MeOH	Yields of **3** (%) in $CuCl_2$/MeOH	Yields of **3** (%) in NaOMe/MeOH
1	**a**	H	H	CH_2	0	78	95	90	83
2	**b**	H	H	O	1	98	97	84	79
3	**c**	H	H	O	2	70	86	70	73
4	**d**	H	Me	O	1	85	91	90	81
5	**e**	H	Me	O	2	60	96	90	88
6	**f**	Me	Me	O	1	81	95	89	85
7	**g**	Me	Me	O	2	75	90	89	76
8	**h**	H	OMe	O	2	60	92	86	85

The reaction with $NiCl_2$ to effect Favorskii type rearrangement was also applied to 4-bromo-2,3,4,5-tetrahydronaphth[2,1-*b*]oxepin-5-one (**5**) and its regioisomer 4-bromo-2,3,4,5-tetrahydronaphth[1,2-*b*]oxepin-5-one (**8**) resulting in the formation of rearranged carboxylic acid esters **6** and **9** in 92 and 95% yield respectively as shown in Scheme 2. Our method using $NiCl_2$ for synthesis of these derivatives demonstrates a new useful and convenient route. However, Maiti et al.[21] used $ZnCl_2$ for the synthesis of a number of cyclic α-bromo ketones and their acetals from α-bromocycloalkyl aryl ketone and corresponding acetals in 22-91% yields while our method using $NiCl_2$ leads to 86-97% yields of the rearranged products.



Scheme 2

Although the mechanism of the present reaction is not clear, the first step is presumably the complexation of bromine atom of ketone carbonyl with nickel chloride **10**, followed by the attack of methoxy group and the elimination of bromide anion taking place simultaneously to form **11**. **11** undergoes ring contraction to form **12** which on deprotonation gave desired product **13** as shown in Figure 1.

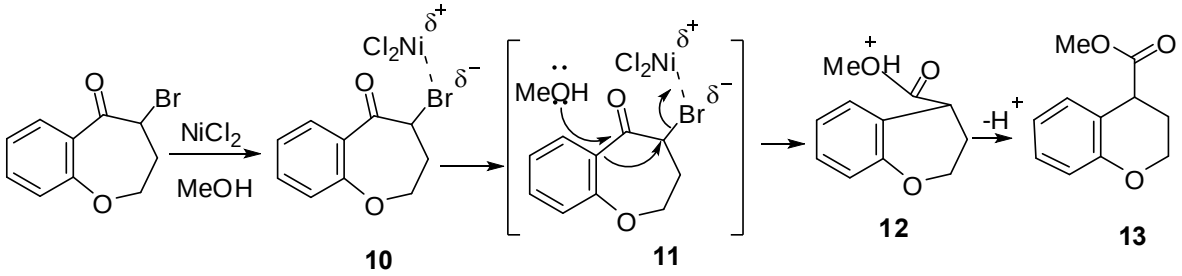


Figure 1

Due to the marked pharmacological and biological activities[11-20] of benzopyran and 1-benzoxepine derivatives, our method provides a convenient and useful route to synthesis of different benzopyran and

benzoxepine derivative. Further work to synthesize saturated α-halo alkanones viz. cyclopropanone-type intermediate is in progress.

EXPERIMENTAL

Melting points are uncorrected. IR spectra were recorded on a Perkin-Elmer model 137 spectrometer. ^{1}H NMR (200 MHz) spectra were recorded on a Perkin-Elmer model R-32 spectrometer in $CDCl_3$ using TMS as internal standard and mass spectra on Joel-JMS-D-300 spectrometer.

General procedure for the synthesis of α-bromoketones 2(a-h): Br_2 (1.60g, 10 mmol) was added to a stirred solution of ketone **1(a-h)** (10 mmol) in dry Et_2O at 0 ^{o}C. The reaction mixture was further stirred at rt for 3 h. The resulting solution was washed with 10 mL 10% aq. $NaHCO_3$ solution and 10 mL of brine. The ether extract was dried (Na_2SO_4) and concentrated *in vacuo* to give crude product. The crude product was purified by column chromatography using silica gel G and hexane and $CHCl_3$ as eluant.

2-Bromo-indanone (**2a**):

Pale yellow solid; mp 39-40 ^{o}C (lit.,[22] mp 37-38.5 ^{o}C); yield 78%; IR (KBr): 1723 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 3.45 (m, 1H, CH_2), 3.88 (m, 1H, CH_2), 4.65 (m, 1H, CH–Br), 7.39-7.91 (m, 4H, phenyl-H); MS (m/z): 211 (M+); Anal. Calcd for C_9H_7BrO: C, 51.18; H, 3.31. Found: C, 51.32; H, 3.40.

3-Bromo-chroman-4-one (**2b**):

Pale yellow solid; mp 96-98 ^{o}C; yield 98%; IR (KBr): 1705 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 4.72 (m, 3H, OCH_2 & CHBr), 6.95-7.26 (m, 2H, ArH), 7.59-7.68 (m, 1H, Ar-H), 8.00-8.12 (m, 1H, Ar-H); MS (m/z): 227 (M^+); Anal. Calcd for $C_9H_7BrO_2$: C, 47.61; H, 3.11. Found: C, 47.54; H, 3.06.

4-Bromo-3, 4-dihydro-1 (2*H*)-benzoxepin-5-one (2c):

Yellow oil; yield 70%; IR (Neat): 1693 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.75 (m, 2H, CH_2), 4.35 (m, 2H, OCH_2), 4.95 (dd, 1H, CHBr), 7.45 (m, 4H, phenyl-H); MS (m/z): 244 (M^++3), 242 (M^++1), 241 (M^+); Anal. Calcd for $C_{10}H_9BrO_2$: C, 49.79; H, 3.73. Found: C, 49.92; H, 3.85.

3-Bromo-6-methyl-chroman-4-one (**2d**):

Yellow solid; mp 75^o C (lit.,[23] mp 74 ^{o}C); yield 85%; IR (KBr): 1696 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.47 (s, 3H, CH_3); 4.61 (m, 3H, CHBr and OCH_2), 7.26-8.01 (m, 3H, phenyl-H); MS (m/z): 242 (M^++1); Anal. Calcd for $C_{10}H_9BrO_2$: C, 49.79; H, 3.73. Found: C, 50.02; H, 3.94.

4-Bromo-7-methyl-3,4-dihydro-1(2*H*)-benzoxepin-5-one (**2e**):

Yellow solid; mp 66-67 ^{o}C (lit.,[24] mp 66-67 ^{o}C); yield 60%; IR (KBr): 1694 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.25 (s, 3H, CH_3), 2.36 (m, 1H, CH), 2.43 (m, 1H, CH), 4.06 (m, 1H, OCH), 4.34 (m, 1H, OCH), 4.90 (dd, 1H, CHBr), 6.89 (d, 1H, phenyl-H), 7.18 (dd, 1H, phenyl-H), 7.47 (d, 1H, phenyl-H). MS (m/z): 256 (M^++1), 255 (M^+); Anal. Calcd for $C_{11}H_{11}BrO_2$: C, 51.76; H, 4.31. Found: C, 51.88; H,

4.40.

3-Bromo-6,7-dimethyl-chroman-4-one (**2f**):

Yellow brown solid; mp 95 ^{o}C, yield 81%; IR (KBr): 1697 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.35 (s, 3H, CH_3), 2.38 (s, 3H, CH_3), 4.62 (m, 3H, CHBr and OCH_2), 7.23 (s, 1H, phenyl-H), 7.94 (s, 1H, phenyl-H); MS (m/z): 255 (M^+); Anal. Calcd for $C_{11}H_{11}BrO_2$: C, 51.76; H, 4.31. Found: C, 51.96; H, 4.48.

4-Bromo-7,8-dimethyl-3,4-dihydro-1(2*H*)-benzoxepin-5-one (**2g**):

Pale yellow solid; mp 81 ^{o}C (lit.,[25] 83-85 ^{o}C) yield 75%; IR (KBr): 1689 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.15 (s, 3H, CH_3), 2.19 (s, 3H, CH_3), 2.41 (m, 1H, CH_2), 2.79 (m, 1H, CH_2), 4.08 (m, 1H, OCH_2), 4.49 (m, 1H, OCH_2), 4.89 (m, 1H CHBr), 6.78 (s, 1H, phenyl-H), 7.47 (s, 1H, phenyl-H); MS (m/z): 269 (M^+); Anal. Calcd for $C_{12}H_{13}BrO_2$: C, 53.53; H, 4.83. Found: C, 53.78; H, 5.02.

4-Bromo-7-methoxy-3,4-dihydro-1(2*H*)-benzoxepin-5-one (**2h**):

Yellow oil; yield 60%; IR (Neat): 1685 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 2.22-2.53 (m, 1H, CH_2), 2.89 (m, 1H, CH_2) 3.81 (s, 3H, OCH_3), 4.14 (m, 1H, OCH_2), 4.40 (m, 1H, OCH_2), 4.99 (m, 1H, CHBr), 7.02 (m, 2H, phenyl-H), 7.23 (m, 1H, phenyl-H). MS (m/z): 272 (M^++1), 271 (M^+); Anal. Calcd for $C_{11}H_{11}BrO_3$: C, 48.70; H, 4.05. Found: C, 48.94; H, 4.18.

General procedure for base catalyzed Favorskii type rearrangement of 2(a-h): Synthesis of carboxylic acid esters 3(a-h):

a) General procedure for $NiCl_2$ promoted Favorskii type rearrangement of cyclic α-bromo ketones 2(a-h): $NiCl_2$ (390 mg; 3mmol) was added to a stirred solution of α-bromo ketones **2(a-h)** (1 mmol) in MeOH (10 mL) under N_2. The reaction mixture was refluxed for 36 h and MeOH distilled off from the reaction mixture. The residue was concentrated *in vacuo* and 10 mL of H_2O was added to the reaction mixture. The reaction mixtrure was extracted with $CHCl_3$ (15 mL) and extract was washed with 10 mL of brine, dried (Na_2SO_4) and concentrated *in vacuo* to yield product **3(a-h)**.

b) $CuCl_2$ was used in place of $NiCl_2$ to effect Favorskii type rearrangement of 2 (a-h): analogous reaction takes place and **3(a-h)** were formed in 70-90% yields (Table 1).

c) General procedure for MeONa catalyzed Favorskii type rearrangement of cyclic α-bromoketones 2(a-h): α-bromo ketones **2(a-h)** (5 mmol) was added to a stirred solution of MeONa [prepared from 230 mg (0.01g atom) of Na in 10 mL of MeOH] and the mixture was stirred with refluxing for 2 h at 80^{o}C. The resulting solution was concentrated *in vacuo*, H_2O (15 mL) added and the mixture was extracted with $CHCl_3$ (20 mL), dried (Na_2SO_4) and concentrated *in vacuo* to give **3(a-h**).

Methyl 1,2-dihydrocyclobutabenzene-1-carboxylate (**3a**): [26]

Oil; IR (neat): 1739 (C=O) cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 3.40 (m, 2H, CH_2), 3.67 (s, 3H, OCH_3) 4.10 (t, 1H,

CH), 7.15- 7.32 (m, 4H, phenyl-H); MS (m/z): 162 (M^+); Anal. Calcd for $C_{10}H_{10}O_2$: C, 74.06; H, 6.21. Found: C, 73.98; H, 6.17.

Methyl 2,3-dihydrobenzofuran-3-carboxylate (3b):[27]

For spectral and physical data of **3b** refer to http://pubs.acs.org.OL0157858

Methyl chroman-4-carboxylate (**3c**):[21]

For spectral and physical data of **3b** refer to reference 21.

Methyl 5-methyl-2,3-dihydrobenzofuran-3-carboxylate (**3d**):[28]

Pale yellow oil; IR (neat): 1737 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.33 (s, 3H, Me), 3.06 (m, 2H, OCH_2), 3.85 (s, 3H, OMe), 4.33 (m, 1H, CH), 6.92 (m, 1H, phenyl-H), 7.36 (m, 2H, phenyl-H); MS (m/z): 193 (M^++1); Anal. Calcd for $C_{11}H_{12}O_3$: C, 68.74; H, 6.29. Found: C, 68.57; H, 6.23.

Methyl 6-methylchroman-4-carboxylate (**3e**):

Oil, IR (neat): 1723 cm^{-1}; ^1H NMR ($CDCl_3$): δ 1.91 (m, 2H, CH_2), 2.32 (s, 3H, CH_3), 3.70 (s, 3H, OCH_3), 3.97 (t, J=4.0 Hz, 1H, CH), 4.19 (t, J=4.0 Hz, 2H, OCH_2), 6.87-7.08 (m, 2H, phenyl-H), 7.55 (s, 1H, phenyl-H); MS (m/z): 193 (M^++1); Anal. Calcd for $C_{12}H_{14}O_3$: C, 69.88; H, 6.84. Found: C, 69.78; H, 6.80.

Methyl 5,6-dimethyl-2,3-dihydrobenzofuran-3-carboxylate (**3f**):

Oil; IR (neat): 1739 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$); δ 2.35 (s, 3H, CH_3), 2.38 (s, 3H, CH_3), 3.90 (t, 3H, CH_3), 4.20 (t, 1H, CH), 4.58 (m, 2H, OCH_2), 7.23 (s, 1H, phenyl-H), 7.44 (s, 1H, phenyl-H); MS (m/z): 207 (M^++1); Anal. Calcd for $C_{12}H_{14}O_3$: C, 69.88; H, 6.84. Found: C, 69.72; H, 6.88.

Methyl 6,7-dimethylchroman-4-carboxylate (**3g**):

Brown oil; IR (neat): 1726 cm^{-1}; ^1H NMR ($CDCl_3$): 2.14 (m, 2H, CH_2), 2.22 (s, 3H, CH_3), 2.23 (s, 3H, CH_3), 3.79 (s, 3H, OCH_3), 3.88 (t, J=4.0 Hz, 1H, CH), 4.10 (t, J=4.0 Hz, 2H, OCH_2), 6.72 (s, 1H, phenyl-H), 7.41 (s, 1H, phenyl-H); MS (m/z) 220 (M^++1); Anal. Calcd for $C_{13}H_{16}O_3$: C, 70.89; H, 7.32. Found: C, 70.79; H, 7.28.

Methyl 6-methoxychroman-4-carboxylate (**3h**):

Yellow oil; IR (Neat): 1726 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$): 2.15 (m, 2H, CH_2), 3.70 (s, 3H, CH_3), 3.80 (s, 3H, OCH_3), 4.04 (t, J=4.01 Hz, 1H, CH), 4.45 (t, J=4.0 Hz, 2H, OCH_2), 6.92-7.26 (m, 3H, phenyl-H); MS (m/z): 223 (M^++1); Anal. Calcd for $C_{12}H_{14}O_4$: C, 64.85; H, 6.35. Found: C, 64.76; H, 6.31.

2-Bromo-3,4-dihydronaphtho[2,1-*b*]oxepin-1(2*H*)-one (**5**):

3,4-dihydronaphtho[2,1-*b*]oxepin-1(2*H*)-one (**4**) on reaction with Br_2 in Et_2O, according to the procedure followed for **2(a-h)** yielded dull colored solid; mp 93 ^oC; yield 78%; IR (KBr): 1685 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$): δ 3.43 (m, 2H, CH_2), 4.22 (t, J=7.0 Hz, 2H, OCH_2), 5.85 (m, 1H, CHBr), 7.5-8.27 (m, 6H, naphth-H); MS (m/z): 292 (M^++1), 291 (M^+); Anal. Calcd for $C_{14}H_{11}BrO_2$: C, 57.76; H,

3.81. Found: C, 57.94; H, 3.86.

Methyl 2,3-dihydro-1*H*-benzo[*f*]chromene-1-carboxylate (6):

2-Bromo-3,4-dihydronaphtho[2,1-*b*]oxepin-1(2*H*)-one (**5**) on reaction with $NiCl_2$ in MeOH according to the procedure followed for **2(a-h)** yielded methyl 2,3-dihydro-1*H*-benzo[*f*]chromene-1-carboxylate (**6**) as an oil; IR (neat): 1738 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$): 1.65 (m, 2H, CH_2), 3.50 (t, J=4.0 Hz, 2H, OCH_2), 3.85 (s, 3H, OMe), 4.02 (t, J=4.0 Hz, 1H, CH), 7.10-8.0 (m, 6H, naphth-H); MS (m/z): 243 (M^++1); Anal. Calcd for $C_{15}H_{14}O_3$: C, 74.36; H, 5.82. Found: C, 74.25; H, 5.80.

4-Bromo-3,4-dihydronaphtho[1,2-*b*]oxepin-5(2*H*)-one (8):

3,4-dihydronaphtho[1,2-*b*]oxepin-5(2*H*)-one (**7**) on reaction with Br_2 in Et_2O, according to the procedure followed for **2(a-h)** yielded light brown colored solid; mp 106 ^oC; yield 84%; IR (KBr): 1680 cm^{-1}; ^1H NMR ($CDCl_3$): δ 3.39-3.47 (m, 2H, CH_2), 4.20 (t, J=7 Hz, 2H, OCH_2), 5.67 (m, 1H, CHBr), 7.56-8.20 (m, 6H, naphth-H); MS (m/z): 292 (M^++1), 291 (M^+); Anal. Calcd for $C_{14}H_{11}BrO_2$: C, 57.76; H, 3.81. Found: C, 57.66; H, 3.79.

Methyl 3,4-dihydro-2*H*-benzo[*h*]chromene-4-carboxylate (9):

4-Bromo-3,4-dihydronaphtho[1,2-*b*]oxepin-5(2*H*)-one (**8**) on reaction with $NiCl_2$ in MeOH according to the procedure followed for **2(a-h**) yielded methyl 3,4-dihydro-2*H*-benzo[*h*]chromene-4-carboxylate (**9**) as an oil; IR (neat): 1734 cm^{-1}; ^1H NMR ($CDCl_3$): 1.59 (m, 2H, CH_2), 3.46 (t, J=4.0 Hz, 2H, OCH_2), 3.79 (s, 3H, OMe), 3.92 (t, J=4.0 Hz, 1H, CH), 6.80-7.84 (m, 6H, naphth-H); Anal. Calcd for $C_{15}H_{14}O_3$: C, 74.36; H, 5.82. Found: C, 74.24; H, 5.78.

ACKNOWLEDGMENTS

A.K.A. thanks, C.S.T., Lucknow, India for Junior Research Fellowship, K.A.S. thanks U.G.C., New Delhi, India for award of a Junior Research Fellowship and H.K.M. thanks U.G.C., New Delhi, India for Senior Research Fellowship.

REFERENCES AND NOTES

1. P. J. Chenier, *J. Chem. Edu.*, 1978, **55**, 286 and references therein.
2. L. F. Silva Jr., *Tetrahedron*, 2002, **58**, 9137.
3. (a) T. Satoh, K. Oguro, J. Shishikura, N. Kanetaka, R. Okada, and K. Yamakawa, *Tetrahedron Lett.*, 1992, **33**, 1455; (b) T. Satoh, S. Motohashi, S. Kimura, S. Kimura, N. Tokutake, and K. Yamakawa, *Tetrahedron Lett.*, 1993, **34**, 4823.
4. S. Braverman, M. Cherkinsky, E. V. K. S. Kumar, and H. E. Gottlieb, *Tetrahedron*, 2000, **56**, 4521.
5. T. Kitayama and T. Okamoto, *J. Org. Chem.*, 1999, **64**, 2667.
6. M. Harmata, G. Bohnert, L. Kurti, and C. L. Barnes, *Tetrahedron Lett.*, 2002, **43**, 2347.

7. V. K. Tandon and R. B. Chhor, *Lett. in Org. Chem.*, 2004, **1**, 40.
8. V. K. Tandon and M. Kumar, *Tetrahedron Lett.*, 2004, **45**, 4185.
9. V. K. Tandon and R. B. Chhor, *Synth. Commun.*, 2001, **31**, 1727.
10. V. K. Tandon, A. Sharon, R. Bandichhor, and P. R. Maulik, *Acta Cryst.*, 2002, **E58**, 869.
11. M. Shiraishi, Y. Aramaki, M. Seto, H. Imoto, Y. Nishikawa, N. Kanzaki, M. Okamoto, H. Sawada, O. Nishimura, M. Baba, and M. Fujino, *J. Med. Chem.*, 2000, **43**, 2049.
12. P. D. Gupta, A. Pal, A. Roy, and D. Mukherjee, *Tetrahedron Lett.*, 2000, **41**, 7563.
13. (a) M. Shiraishi, M. Baba, M. Seto, N. Kanzaki, and O. Nishimura, Japanese Pat. Appl. 1999/127, 724, 1999 (*Chem. Abstr.*, 2000, **133**, 362714q); (b) K. Takashima, Y. Iizawa, M. Shiraishi, Y. Sugihara, and M. Baba, Japanese Pat. Appl. 2002/141, 657, 2002 (*Chem. Abstr.*, 2003, **139**, 341780s).
14. S. Kloubert, M. Mathé-Allainmat, J. Andrieux, and M. Langlois, *Synth. Commun.*, 2000, **30**, 2873.
15. (a) M. Brunet, J. J. Zeilter, J. J. Berthelon, F. Contard, G. Augert, and D. Guerrier, French Pat. Appl. 1998/16, 574, 1998 (*Chem. Abstr.*, 2000, **133**, 89445j); (b) Y. Auberson, C. Betschart, S. Flohr, R. Glalthar, O. Simic M. Tintelnot-Blomly, T. J. Troxler, E. Vangrevelinghe, and S. J. Veenstra, British Pat. Appl. 2003/17, 491, 2003 (*Chem. Abstr.*, 2005, **142**, 240329h).
16. V. K. Tandon, M. Kumar, A. K. Awasthi, H. O. Saxena, and G. K. Goswamy, *Bioorg. Med. Chem. Lett.*, 2004, **14**, 3177.
17. V. K. Tandon, K. A. Singh, A. K. Awasthi, J. M. Khanna, B. Lal, and N. Anand, *Bioorg. Med. Chem. Lett.*, 2004, **14**, 2867.
18. V. K. Tandon and A. Chandra, *Tetrahedron Lett.*, 1993, **34**, 4403.
19. V. K. Tandon, J. M. Khanna, A. Chandra, and N. Anand, *Tetrahedron*, 1990, **46**, 2871.
20. V. K. Tandon, A. Chandra, P. R. Dua, and R. C. Srimal, *Arch. Pharm.*, 1993, **326**, 221.
21. S. B. Maiti, S. R. R. Chaudhuri, and A. Chatterjee, *Synthesis*, 1987, **9**, 806.
22. H. O. House, V. Paragamian, R. S. Ro, and D. J. Wluka, *J. Am. Chem. Soc.*, 1960, **82**, 1452.
23. J. Colonge and A. Guyol, *Bull. Soc. Chim. France.*, 1958, 329.
24. V. K. Tandon, J. M. Khanna, N. Anand, R. C. Srimal, C. R. Prasad, and K. Kar, *Ind. J. Chem.*, 1975, **13**, 1.
25. G. Fontaine, *Ann. Chim. (Paris).*, 1968, **3**, 179.
26. a) F. M. Nongrum and B. Myrboh, *Synthesis*, 1987, **9**, 845; b) H. Tomioka and K. Taketsuji, *J. Org. Chem.*, 1993, **58**, 4196.
27. H. M. L. Davies, M. V. A. Grazini, and E. Aouad, *Org. Lett.*, 2001, **3**, 1475.
28. E. A. Boyle, F. R. Mangan, R. E. Markwell, S. A. Smith, M. J. Thomson, R. W. Ward, and P. A. Wyman, *J. Med. Chem.*, 1986, **29**, 894.