Journal of Sulfur Chemistry
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713926081

Regioselective synthesis of pentacyclic heterocycles by the thermal and Lewis acid catalyzed Claisen rearrangement

K. C. Majumdar[a]; A. K. Pal[a]
[a] Department of Chemistry, University of Kalyani, Kalyani, West Bengal, India

To cite this Article Majumdar, K. C. and Pal, A. K.(2009) 'Regioselective synthesis of pentacyclic heterocycles by the thermal and Lewis acid catalyzed Claisen rearrangement', Journal of Sulfur Chemistry, 30: 5, 481 — 489
To link to this Article: DOI: 10.1080/17415990902725709
URL: http://dx.doi.org/10.1080/17415990902725709

Journal of Sulfur Chemistry
Vol. 30, No. 5, October 2009, 481–489

Taylor & Francis
Taylor & Francis Group

Regioselective synthesis of pentacyclic heterocycles by the thermal and Lewis acid catalyzed Claisen rearrangement

K.C. Majumdar* and A.K. Pal

Department of Chemistry, University of Kalyani, Kalyani 741235, West Bengal, India

(*Received 2 October 2008; final version received 29 December 2008*)

[6,6]- and [6,5]-fused hithero unreported pentacyclic heterocycles have been regioselectively synthesized from 4-(4′-aryloxybut-2′-ynylthio)thiocoumarin in good yields by the application of thermal as well as catalytic Claisen rearrangement.

Keywords: Claisen rearrangement; Lewis acid catalysis; pyridine hydrotribromide; regioselectivity

1. Introduction

Since its discovery in 1912, Claisen rearrangement has gained a predominant role in organic synthesis due to its ability to form new carbon–carbon bonds (*1*) devoid of side reactions. A high level of stereocontrol secured its widespread use in the synthesis of natural products and medicinal agents (*1*). The traditional methodology for accomplishing the rearrangement is based on a thermally controlled procedure. However, the development of new methodologies employing catalysts in the Claisen rearrangement has been the focus of many recent investigations in organic synthesis (*2*). Over the last few years, we have synthesized various coumarin-annulated heterocycles by using the Claisen rearrangement (*3*). Coumarin and its derivatives are important because of their physiological and biological activities (*4*). 3-Alkyl- and 4-alkyl coumarins (*5*) are well known for their anthelmintic, hypnotic, insecticidal, antifungal, anticoagulant effect on blood and for their diuretic properties. Here, we describe our strategy for the regioselective synthesis of [6,6]- and [6,5]-fused pentacyclic thiocoumarin derivatives from 4-(4′-aryloxybut-2′-ynylthio)thiocoumarins by the application of thermal as well as aluminum chloride-catalyzed Claisen rearrangement.

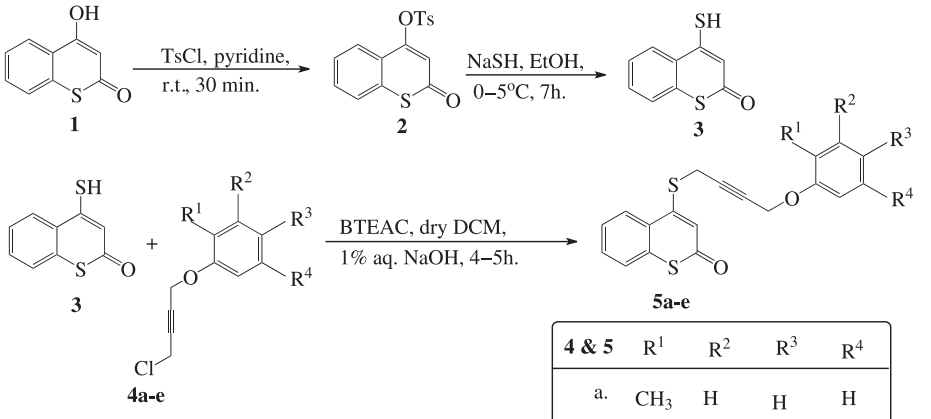
2. Results and discussion

The requisite starting materials for our present study, **5a–e**, were synthesized by the phase transfer catalyzed alkylation of 4-marcapto-thiocoumarin **3** with different 1-aryloxy-4-chlorobut-2-ynes

*Corresponding author. Email: kcm_ku@yahoo.co.in

ISSN 1741-5993 print/ISSN 1741-6000 online

DOI: 10.1080/17415990902725709
http://www.informaworld.com

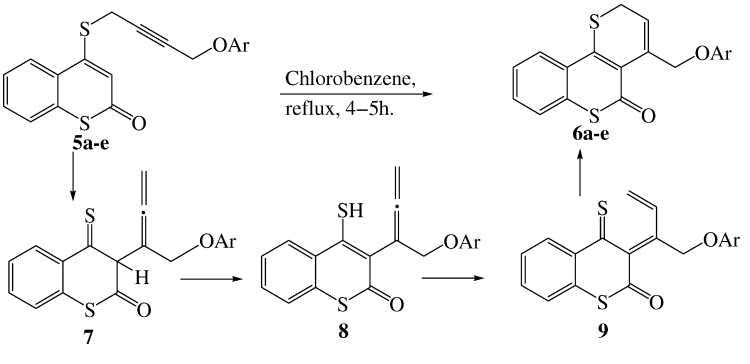


4 & 5	R^1	R^2	R^3	R^4
a.	CH_3	H	H	H
b.	CH_3	CH_3	H	H
c.	H	H	Cl	H
d.	H	CH_3	Cl	H
e.	H	CH_3	Cl	CH_3

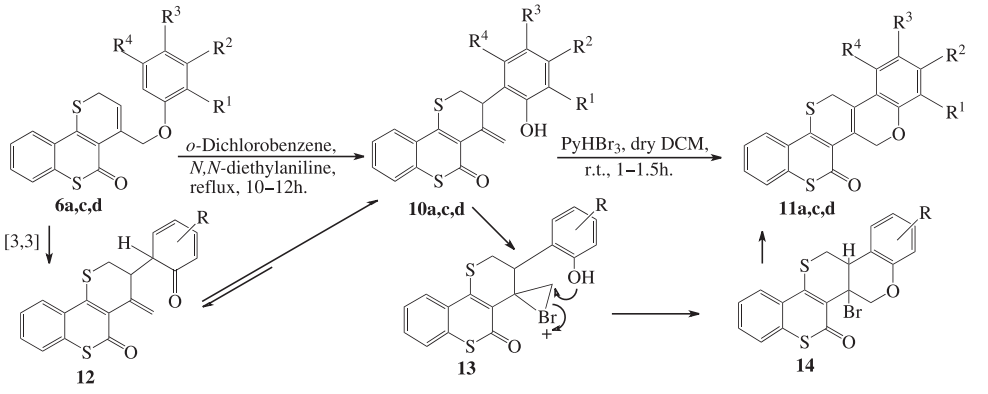
Scheme 1.

4a–e in 72–85% yields. Compound **3** was prepared *in situ* from 4-tosyloxythiocoumarin **2**, which was in turn prepared from 4-hydroxy-thiocoumarin **1** (Scheme 1).

Substrates **5a–e** contain an aryl propargyl ether moiety as well as a vinyl propargyl sulfide moiety and thus offer scope for two different possibilities of [3,3]-sigmatropic rearrangement. From the literature, it is evident that aliphatic Claisen rearrangement requires lower activation energy than its aromatic counterpart, as aromatic sextet is disturbed in the transition state. Therefore, substrate **5a** was refluxed in chlorobenzene (132° C) and the progress of the reaction was monitored by TLC. Complete conversion was achieved in 3 h and a yellow solid **6a** in 92% yield was obtained. The product was identified from its elemental analysis and spectroscopic data. Substrates **5b-e** on similar treatment afforded compounds **6b-e** in 78–90% yields (Scheme 2).The formation of products **6a–e** from substrates **5a–e** may be explained by considering an initial [3,3] sigmatropic rearrangement of sulfides **5a–e** to give allenyl intermediates **7**. Enolization followed by [1,5] hydrogen shift and subsequent 6π-electrocyclic ring closure afforded products **6a–e** (Scheme 2).



Scheme 2.



Scheme 3.

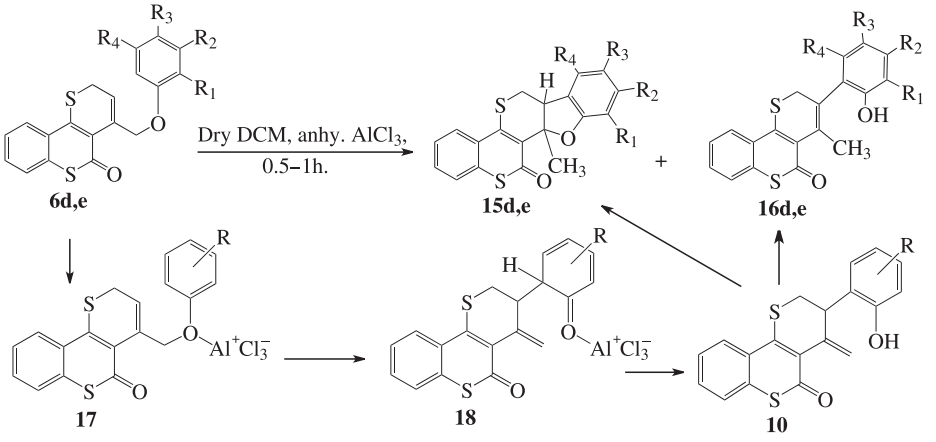
Compound **6a** contains an allyl-aryl ether moiety and, therefore, it is a suitable substrate for the second [3,3] sigmatropic rearrangement. Compound **6a** was subjected to heating in refluxing *o*-dichlorobenzene in the presence of *N*,*N*-diethylaniline for 12 h to give the phenolic product **10a** in 62% yield. Appearance of a peak in the region 3290 cm^{-1} confirmed the presence of a phenolic –OH group in compound **10a**. ^{1}H NMR spectrum of compound **10a** showed signals at δ 5.46 and δ 5.87, indicating the presence of an *exo*-cyclic double bond. Compound **10a** was characterized from its elemental analysis and spectroscopic data. On similar treatment, compounds **6c,d** produced **10c,d** in 58 and 65% yields, respectively (Scheme 3).

The formation of **10a,c,d** from **6a,c,d** may be easily explained by a [3,3] sigmatropic rearrangement followed by enolization (Scheme 3). As a part of our ongoing research work for the synthesis of polyheterocyclic compounds, we have earlier made use of pyridine hydrotribromide (*6*), hexamine hydrotribromide (*7*) and *N*-iodosuccinamide (*8*) for regioselective cyclization of *o*-cyclohex-2-enyl phenols. We therefore treated the compounds **10a,c,d** with pyridine hydrotribromide at 0–5° C for 1–1.5 h, to afford the cyclized products **11a,c,d** in almost quantitative yields (Scheme 3).

The products were characterized by their ^{1}H NMR, IR and mass spectra. Disappearance of the phenolic –OH group in the IR spectrum and the appearance of two *exo*-cyclic protons in the ^{1}H NMR spectrum confirmed the formation of compounds **11a,c,d**. The formation of products can be easily explained by the initial formation of cyclic bromonium ions followed by '*6-endo*' cyclization and elimination of HBr to give [6,6]-fused products **11** (Scheme 3).

We have also attempted the Lewis acid-catalyzed Claisen rearrangement (*9*) of the substrates **6d,e**. Among the different catalysts reported in the literature, $AlCl_3$ and its derivatives are known to be efficient for the Claisen rearrangement (*10*). Therefore, substrates **6d,e** on treatment with anhydrous $AlCl_3$ in dry DCM at RT for 30–60 min gave cyclized products **15d,e** (43 and 47%), along with isomerized products **16d,e** (19 and 24%) (Scheme 4). The formation of products **15d,e** and **16d,e** from **6d,e** can be rationalized by a series of steps involving an initial charge accelerated [3,3] sigmatropic rearrangement of **6d,e** to give **18** via ether–oxygen–$AlCl_3$ complex **17**, followed by rapid tautomerization and proton exchange to give intermediate **10,** which on 5-*exo* cyclization afforded products **15d,e**. [1,3] prototropic shift in intermediate **10** may give compounds **16d,e** (Scheme 4).

In conclusion, we have successfully extended the *thio*-Claisen and *oxy*-Claisen rearrangement of compounds **6a–e** under thermal as well as aluminum chloride-catalyzed conditions. These methodologies are simple, offer a high level of regioselectivity and are efficient for the formation of [6,6]- and [6,5]-fused heterocycles.



Scheme 4.

3. Experimental

Melting points were determined in an open capillary and are uncorrected. IR spectra were recorded on a Perkin-Elmer L120-000A spectrometer (ν_{max} in cm^{-1}) on KBr disks. ^1H NMR (300, 400 and 500 MHz) spectra were recorded on Bruker DPX-300, Bruker DPX-400 and Bruker DPX-500 spectrometers in $CDCl_3$ (chemical shift in δ with TMS as internal standard). Silica gel (60–120, 230–400 mesh, Spectrochem, India) was used for chromatographic separation. Silica gel G (E-Merck, India) was used for TLC. Petroleum ether refers to the fraction boiling between 60° C and 80° C.

3.1. *General procedure for the preparation of 4-tosyloxy thiocoumarin (2)*

4-Hydroxythiocoumarin **1** (1.78 g, 10 mmol) was dissolved in pyridine (20 mL) and *p*-toluene sulphonyl chloride (1.98 g, 10 mmol) was added. The reaction mixture was stirred for about 30 min and allowed to attain RT. It was then poured into crushed ice and left overnight. The precipitate was then filtered, washed with water and dried. The solid material was recrystallized from methanol.

3.2. *General procedure for the preparation of 4-mercaptothiocoumarin (3)*

NaSH (0.29 g, 5.28 mmol) was taken in ethanol (50 mL) and stirred at 0–5° C. Then ethanolic solution (100 mL) of compound **2** (1 g, 3.52 mmol) was added dropwise for a period of 2 h. The resulting reaction mixture was then allowed to attain RT and stirring was continued for another 5 h. The solvent ethanol was removed under reduced pressure. The residue was acidified with ice cold 50% aq. HCl to maintain pH ~2 and extracted with DCM (3 × 25 mL). The DCM extract was washed with water (3 × 20 mL), brine (25 mL) and dried (Na_2SO_4). Removal of solvent under reduced pressure furnished a crude product **3**. This crude product **3** was used in the subsequent phase transfer-catalyzed reaction without further purification.

3.3. *General procedure for the preparation of compounds (5a–e)*

To a well stirred solution of 4-mercapto thiocoumarin **3** (0.5 g, 2.57 mmol) and 1-aryloxy-4-chloro-but-2-ynes (**4a–e**, 3.22 mmol) in DCM (50 mL), a solution of benzyl triethyl ammonium

chloride (0.02 g, 0.1 mmol) in 1% aq. NaOH (50 mL) was added and the mixture was stirred for 4–5 h at RT. The reaction mixture was then diluted with water (25 mL) and extracted with DCM (3×20 mL). The organic layer was washed with water (3×20 mL), saturated brine solution (25 mL) and dried (Na_2SO_4). The solvent was removed and residual mass was subjected to column chromatography over silica gel (60–120 mesh) using petroleum ether:ethyl acetate (1:9) as eluent to afford products **5a–e**.

*4-{[4-(2-Methylphenoxy)-2-butynyl]sulfanyl}-2H-2-thiochromenone (**5a**)*

Yield: 77%; yellow solid; mp: 146–148° C; IR (KBr) υ_{max} : 2919, 1612, cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.21 (s, 3H), 3.79 (t, $J = 1.8$ Hz, 2H), 4.68 (t, $J = 2.0$ Hz, 2H), 6.35 (s, 1H), 6.89–8.01 (m, 8H) ppm; MS: $m/z = 352$ (M^+); Anal. calcd for $C_{20}H_{16}O_2S_2$: C, 68.15; H, 4.58; found: C, 68.38; H, 4.65%.

*4-{[4-(3,4-Dimethylphenoxy)-2-butynyl]sulfanyl}-2H-2-thiochromenone (**5b**)*

Yield: 72%; yellow solid; mp: 156–157° C; IR (KBr) υ_{max}: 2922, 1615, cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.18 (s, 3H), 2.20 (s, 3H), 3.79 (s, 2H), 4.67 (s, 2H), 6.50 (s, 1H), 6.97–8.02 (m, 7H) ppm; MS: $m/z = 366$ (M^+); Anal. calcd for $C_{21}H_{18}O_2S_2$: C, 68.82; H, 4.95; found: C, 68.61; H, 4.98%.

*4-{[4-(4-Chlorophenoxy)-2-butynyl]sulfanyl}-2H-2-thiochromenone (**5c**)*

Yield: 83%; yellow solid; mp: 132–133° C; IR (KBr) υ_{max}: 2915, 1609, cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 3.80 (s, 2H), 4.67 (s, 2H), 6.53 (s, 1H), 6.83–8.04 (m, 8H) ppm; MS: $m/z = 372$, 374 (M^+); Anal. calcd for $C_{19}H_{13}ClO_2S_2$: C, 61.20; H, 3.51; found: C, 61.09; H, 3.69%.

*4-{[4-(4-Chloro-3-methylphenoxy)-2-butynyl]sulfanyl}-2H-2-thiochromenone (**5d**)*

Yield: 79%; yellow solid; mp: 160–162° C; IR (KBr) υ_{max}: 2920, 1613, cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.24 (s, 3H), 3.79 (t, $J = 2.2$ Hz, 2H), 4.76 (t, $J = 2.2$ Hz, 2H), 6.51 (s, 1H), 6.91–8.00 (m, 7H) ppm; MS: $m/z = 386$, 388 (M^+); Anal. calcd for $C_{20}H_{15}ClO_2S_2$: C, 62.08; H, 3.91; found: C, 61.79; H, 3.79%.

*4-{[4-(4-Chloro-3,5-dimethylphenoxy)-2-butynyl]sulfanyl}-2H-2-thiochromenone compound (**5e**)*

Yield: 85%; yellow solid; mp: 149–151° C; IR (KBr) υ_{max}: 2914, 1617, cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.26 (s, 6H), 3.78 (t, $J = 1.6$ Hz, 2H), 4.69 (t, $J = 1.6$ Hz, 2H), 6.48 (s, 1H), 6.62–7.99 (m, 6H) ppm; MS: $m/z = 400$, 402 (M^+); Anal. calcd for $C_{21}H_{17}ClO_2S_2$: C, 62.91; H, 4.27; found: C, 62.97; H, 4.23%.

3.4. *General procedure for the preparation of compounds (6a–e)*

Compound **5a–e** (1.5 mmol) was heated in refluxing chlorobenzene (5 mL) for 4–5 h. The reaction was monitored by TLC. Chlorobenzene was removed by elution of the silica-gel column with petroleum ether (60–80° C). Elution of the column with petroleum ether:ethyl acetate (19:1) furnished products **6a–e**.

*4-[(2-Methylphenoxy)methyl]-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**6a**)*

Yield: 92%; yellow solid; mp: 181–183° C; IR (KBr) υ_{max}: 2922, 1602 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.15 (s, 3H), 3.31 (d, $J = 6.15$ Hz, 2H), 5.03 (s, 2H), 6.24 (t, $J = 6.1$, 1H), 6.62–7.99 (m, 8H) ppm; MS: $m/z = 352$ (M^+); Anal. calcd for $C_{20}H_{16}O_2S_2$: C, 68.15; H, 4.58; found: C, 68.02; H, 4.61%.

*4-[(3,4-Dimethylphenoxy)methyl]-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**6b**)*

Yield: 83%; yellow solid; mp: 188–189° C; IR (KBr) υ_{max}: 2925, 1608 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.21 (s, 3H), 2.22 (s, 3H), 3.31 (d, $J = 6.1$ Hz, 2H), 5.00 (s, 2H), 6.25 (t, $J = 6.1$, 1H), 6.91–8.21 (m, 7H) ppm; MS: $m/z = 366$ (M^+); Anal. calcd for $C_{21}H_{18}O_2S_2$: C, 68.82; H, 4.95; found: C, 69.02; H, 5.11%.

*4-[(4-Chlorophenoxy)methyl]-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**6c**)*

Yield: 78%; yellow solid; mp: 201–203° C; IR (KBr) υ_{max}: 2916, 1601 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 3.30 (d, $J = 6.1$ Hz, 2H), 5.00 (s, 2H), 6.20 (t, $J = 6.1$, 1H), 6.78–8.22 (m, 8H) ppm; MS: $m/z = 372$, 374 (M^+); Anal. calcd for $C_{19}H_{13}ClO_2S_2$: C, 61.20; H, 3.51; found: C, 61.26; H, 3.63%.

*4-[(4-Chloro-3-methylphenoxy)methyl]-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**6d**)*

Yield: 90%; yellow solid; mp: 197–198° C; IR (KBr) υ_{max}: 2923, 1596 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): $\delta_H = 2.14$ (s, 3H), 3.33 (d, $J = 6.2$ Hz, 2H), 5.01 (d, $J = 1.1$ Hz, 2H), 6.22 (m, 1H), 6.69–8.27 (m, 7H) ppm; MS: $m/z = 386$, 388 (M^+); Anal. calcd for $C_{20}H_{15}ClO_2S_2$: C, 62.08; H, 3.91; found: C, 62.25; H, 3.82%.

*4-[(4-Chloro-3,5-dimethylphenoxy)methyl]-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**6e**)*

Yield: 87%; yellow solid; mp: 185–186° C; IR (KBr) υ_{max}: 2921, 1605 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): $\delta_H = 2.21$ (s, 6H), 3.34 (d, $J = 6.2$ Hz, 2H), 5.08 (d, $J = 1.0$ Hz, 2H), 6.31 (m, 1H), 6.82–8.24 (m, 6H) ppm; MS: $m/z = 400$, 402 (M^+); Anal. calcd for $C_{21}H_{17}ClO_2S_2$: C, 62.91; H, 4.27; found: C, 62.62; H, 4.04%.

3.5. *General procedure for the preparation of compounds (10a,c,d)*

Compounds **6a,c,d** (1 mmol) were refluxed in *o*-dichlorobenzene (10 mL) in the presence of *N,N*-diethyl aniline (seven to eight drops) for about 10–12 h. The reaction mixture was allowed to cool and directly subjected to column chromatography over silica gel. The compounds **10a,c,d** were obtained as yellow solid materials when the column was eluted with (3:17) ethyl acetate–petroleum ether.

*3-(2-Hydroxy-3-methylphenyl)-4-methylene-3,4dihydro-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**10a**)*

Yield: 62%; yellow solid; mp: 142–144° C; IR (KBr) υ_{max}: 3434, 2923, 1622 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.25 (s, 3H), 3.37–3.52 (m, 2H), 4.26 (t, $J = 6.7$, 1H), 5.08 (s, 1H), 5.46

(s, 1H), 5.87 (s, 1H), 6.80–8.16 (m, 7H) ppm; MS: $m/z = 352$ (M^+); Anal. calcd for $C_{20}H_{16}O_2S_2$: C, 68.15; H, 4.58; found: C, 68.21; H, 4.44%.

*3-(5-Chloro-2-hydroxyphenyl)-4-methylene-3,4dihydro-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**10c**)*

Yield: 58%; yellow solid; mp: 138–139° C; IR (KBr) υ_{max}: 3430, 2928, 1618 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 3.37–3.43 (m, 2H), 4.41 (t, $J = 6.7$, 1H), 5.41 (s, 1H), 5.79 (s, 1H), 6.00 (s, 1H), 7.04–8.16 (m, 7H) ppm; MS: $m/z = 372$, 374 (M^+); Anal. calcd for $C_{19}H_{13}ClO_2S_2$: C, 61.20; H, 3.51; found: C, 61.03; H, 3.38%.

*3-(5-Chloro-2-hydroxy-4-methylphenyl)-4-methylene-3,4dihydro-2H,5H-thiopyrano[3,2-c]-thiochromen-5-one (**10d**)*

Yield: 65%; yellow solid; mp: 149–150° C; IR (KBr) υ_{max}: 3427, 2918, 1621 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.22 (s, 3H), 3.37–3.48 (m, 2H), 4.38 (t, $J = 6.7$, 1H), 5.42 (s, 1H), 5.78 (s, 1H), 5.79 (s, 1H), 6.91–8.13 (m, 6H) ppm; MS: $m/z = 386$, 388 (M^+); Anal. calcd for $C_{20}H_{15}ClO_2S_2$: C, 62.08; H, 3.91; found: C, 62.17; H, 3.85%.

3.6. *General procedure for the preparation of compounds (11a,c,d)*

Compounds **10a,c,d** (0.3 mmol) were stirred with pyridine hydrotribromide (0.1 g, 0.3 mmol) in dry DCM (10 mL) at 0–5° C for 1–1.5 h. DCM (20 mL) was added and the reaction mixture was washed with 10% sodium bisulfite (2 × 10 mL), water (3 × 10 mL), saturated brine solution (10 mL), dried (Na_2SO_4) and solvent was removed. Column chromatography of the residual mass gave products **11a,c,d** when it was eluted with (1:19) ethyl acetate–petroleum ether.

*4-Methyl-6,14-dihydro-7H-thiochromeno[3′,4′:5,6]thipyrano[4,3-c]chromen-7-one (**11a**)*

Yield: 81%; yellow solid; mp: 157–158° C; IR (KBr) υ_{max}: 2926, 1601 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.21 (s, 3H), 3.69 (s, 2H), 4.98 (s, 2H), 7.12–8.22 (m, 7H) ppm; MS: $m/z = 350$ (M^+); Anal. calcd for $C_{20}H_{14}O_2S_2$: C, 68.54; H, 4.03; found: C, 68.40; H, 4.06%.

*2-Chloro-6,14-dihydro-7H-thiochromeno[3′,4′:5,6]thiopyrano[4,3-c]chromen-7-one (**11c**)*

Yield: 79%; yellow solid; mp: 160–162° C; IR (KBr) υ_{max}: 2918, 1609 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 3.69 (s, 2H), 5.08 (s, 2H), 7.09–8.23 (m, 7H) ppm; MS: $m/z = 370$, 372 (M^+); Anal. calcd for $C_{19}H_{11}ClO_2S_2$: C, 61.53; H, 2.99; found: C, 61.78; H, 3.02.

*2-Chloro-3-methyl-6,14-dihydro-7H-thiochromeno[3′,4′:5,6]thiopyrano[4,3-c]chromen-7-one compound (**11d**)*

Yield: 85%; yellow solid; mp: 169–171° C; IR (KBr) υ_{max}: 2932, 1597 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.21 (s, 3H), 3.69 (s, 2H), 4.97 (s, 2H), 7.06–8.22 (m, 6H) ppm; MS: $m/z = 384$, 386 (M^+); Anal. calcd for $C_{20}H_{13}ClO_2S_2$: C, 62.41; H, 3.40; found: C, 62.62; H, 3.24%.

3.7. *$AlCl_3$ catalyzed reaction of compounds (6d,e)*

Compounds **6d,e** (0.5 mmol) were dissolved in dry DCM (10 mL) and anhydrous $AlCl_3$ (0.006 g, 0.05 mmol) was added. The reaction mixture was stirred at RT for 0.5–1 h. Crushed ice was added to the reaction mixture and extracted with DCM (3×15 mL). The organic extract was washed with 1% HCl (20 mL), water (3×15 mL), brine solution (15 mL) and dried (Na_2SO_4). Removal of the solvent gave a crude mass, which was purified by silica-gel column chromatography using petroleum ether:ethyl acetate (9:1) as eluent to afford the products **15d,e** and **16d,e**.

*8-Chloro-9,11a-dimethyl-6a,11a-dihydro-6H,12H-benzo[b]thiochromeno[3′,4′:5,6]thiopyrano[3,4-d]furan-12-one (**15d**)*

Yield: 43%; yellow solid; mp: 132–134° C; IR (KBr) υ_{max}: 2919, 1619 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.77 (s, 3H), 2.30 (s, 3H), 2.65 (t, $J = 12.5$, 1H), 3.00 (dd, $J = 3.9, 13.1$, 1H), 3.36 (dd, $J = 4.03, 11.9$, 1H), 6.58–8.15 (m, 6H) ppm; MS: $m/z = 386$, 388 (M^+); Anal. calcd for $C_{20}H_{15}ClO_2S_2$: C, 62.08; H, 3.91; found: C, 62.26; H, 3.81%.

*8-Chloro-7,9,11a-trimethyl-6a,11a-dihydro-6H,12H-benzo[b]thiochromeno[3′,4′:5,6]thiopyrano[3,4-d]furan-12-one (**15e**)*

Yield: 47%; yellow solid; mp: 127–129° C; IR (KBr) υ_{max}: 2923, 1615 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.69 (s, 3H), 2.30 (s, 3H), 2.32 (s, 3H), 2.57 (t, $J = 12.9$, 1H), 2.99 (dd, $J = 3.7, 13.1$, 1H), 3.33 (dd, $J = 3.6, 12.7$, 1H), 6.56 (s, 1H), 7.37–8.16 (m, 4H) ppm; MS: $m/z = 400$, 402 (M^+); Anal. calcd for $C_{21}H_{17}ClO_2S_2$: C, 62.91; H, 4.27; found: C, 62.80; H, 4.43%.

*3-(5-Chloro-2-hydroxy-4-methylphenyl)-4-methyl-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**16d**)*

Yield: 19%; yellow solid; mp: 167–168° C; IR (KBr) υ_{max}: 3415, 2913, 1617 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 2.19 (s, 3H), 2.59 (s, 3H), 4.26 (s, 2H), 6.78–7.90 (m, 7H) ppm; MS: $m/z = 386$, 388 (M^+); Anal. calcd for $C_{20}H_{15}ClO_2S_2$: C, 62.08; H, 3.91; found: C, 62.15; H, 3.94%.

*3-(3-Chloro-6-hydroxy-2,4-dimethylphenyl)-4-methyl-2H,5H-thiopyrano[3,2-c]thiochromen-5-one (**16e**)*

Yield: 24%; yellow solid; mp: 171–173° C; IR (KBr) υ_{max}: 3441, 2928, 1611 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): $\delta_H = 2.18$ (s, 3H), 2.22 (s, 3H), 2.59 (s, 3H), 4.27 (s, 2H), 6.70–7.92 (m, 6H) ppm; MS: $m/z = 400$, 402 (M^+); Anal. calcd for $C_{21}H_{17}ClO_2S_2$: C, 62.91; H, 4.27; found: C, 63.18; H, 4.13%.

Acknowledgement

We thank the CSIR (New Delhi) for financial assistance. We also thank the DST (New Delhi) for providing us UV-VIS and FT-IR under the FIST program. One of us (A.P.) is grateful to the CSIR for a Senior Research Fellowship.

References

(1) Zieglar, F.E. *Chem. Rev*. **1988,** *88*, 1423; Wipf, P. *Comprehensive Organic Synthesis*; Trost, B.M. Ed.; Vol. 5; Pergamon; Oxford, 1991, p 827; Castro, A.M.M. *Chem. Rev*. **2004,** *104*, 2939–3002; Majumdar, K.C.; Alam, S.; Chattopadhyay, B. *Tetrahedron* **2008,** 597–643.

(2) Lutz, R.P. *Chem. Rev*. **1984,** *84*, 205–247; Corey, E.J.; Lee, D.H. *J. Am. Chem. Soc*. **1991,** *113*, 4026–4028; Maruoka, K.; Saito, S.; Yamamoto, H. *J. Am. Chem. Soc*. **1995,** *117*, 1165–1166; Kazmaier, U.; Krebs, A. *Ang. Chem. Int. Ed. Engl*. **1995,** *34*, 2012–2014; Yoon, T.P.; Dong V.M.; MacMillan, T.W.C. *J. Am. Chem. Soc*. **1999,** *43*, 9726–9727.

(3) Majumdar, K.C.; Kundu, N.K.; Ghosh, S.K. *Org. Lett*. **2002,** *4*, 2629–2631; Majumdar, K.C.; Saha, S.; De, R.N.; Ghosh, S.K. *J. Chem. Soc. Perkin Trans*. **1993,** *1*, 715–718; Majumdar, K.C.; Chatterjee, P.; Saha, S. *Tetrahed. Lett*. **1998,** *39*, 7147–7148; Majumdar, K.C.; De, R.N.; Khan, A.T.; Chattopadhyay, S.K.; Dey, K.; Patra, A. *J. Chem. Soc. Perkin Trans*. **1988,** *1*, 777–779.

(4) Deana, A.A.; Stokker, G.E.; Schultz, E.M.; Smith, R.L.; Cragoe Jr, E.J.; Russo, H.F.; Watson, L.S. *J. Med. Chem.* **1983,** *26*, 580–585; Gordon, M.; Grover, S.H.; Strothers, J.B. *Can. J. Chem.* **1973,** *51*, 2092–2097; Wenkert, E.; Buckwalter, B.L. *J. Am. Chem. Soc*. **1972,** *94*, 4367–4369.

(5) Wawzoneck, S. *Heterocyclic Compounds*; Elderfield, R.C., Ed.; Wiley: New York, 1951; Vol. 2; p 176; Staunton, J. *Comprehensive Organic Chemistry*; Sammes, P.G., Ed.; Pergamon Press: Oxford, 1979; Vol. 4; p 646; Hepworth, J.D. *Comprehensive Heterocyclic Chemistry*; Bulton, A.J.; Mckillop, A., Eds.; Pergamon Press: Oxford, 1984; Vol. 3, p 799.

(6) Majumdar, K.C.; Kundu, A.K. *Can. J. Chem.* **1995,** *73*, 1727–1732.

(7) Majumdar, K.C.; Kundu, A.K.; Chatterjee, P. *Synth. Commun*. **1996,** *26*, 893–898.

(8) Majumdar, K.C.; Sarkar, S. *Tetrahedron* **2002,** *58*, 8501–8504; Majumdar, K.C.; Kundu, U.K.; Jana, N.K.; Roy, B. *Can. J. Chem.* **2005,** *83*, 63–67.

(9) Borgulya, J.; Nagai, N.; Naruta, Y. *Tetrahed. Lett*. **1985,** *26*, 5129; Bates, D.K.; Jones, M.C. *J. Org. Chem*. **1978,** *43*, 3775–3776.

(10) Majumdar, K.C.; Chattopadhyay, S.K. *Can. J. Chem.* **2006,** *84*, 269–475; Majumdar, K.C.; Islam, R. *Can. J. Chem.* **2006,** *84*, 1632–1639; Majumdar, K.C.; Pal, A.K. *Can. J. Chem.* **2008,** *86*, 72–78; Majumdar, K.C.; Saha, D.; Debnath, P. *Synth. Commun*. **2007,** *37*, 3657–3665.