# Synthesis of Novel Coumarin and Benzocoumarin Derivatives and their Biological and Photophysical Studies



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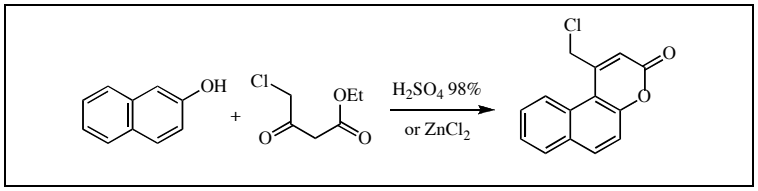
Received October 5, 2006




Several derivatives of coumarin-3*N*-carboxamides (**3-21**) have been prepared *via* the reaction of the coumarin-3-carbonyl chloride (**1**) with a number of nucleophiles. Novel double-headed coumarin-3*N*-carboxamides (**26-33**) were also produced using the same method. The Pechmann-Duisberg reaction was applied to prepare new benzo[*f*]- benzo[*h*]coumarins and 4-(chloromethyl)-pyrano[3,2-*c*]coumarin-2-one (**36-42**). The reaction of 1-chloromethylbenzo[*f*]coumarins (**36**) with cyanide anion under different reaction conditions was also investigated in order to assess its suitability for nucleophilic substitution reactions as well as ring transformation products (**43-49**). Synthesis of 1-((benzo[*d*]thiazol-2-yl)methyl)-9-hydroxybenzo[*f*]coumarin (**50**) represented the first example of methylene bridge-head heterocycle-containing benzo[*f*]coumarin. Some of the newly prepared coumarins exhibited anti-bacterial activity against Gram Positive and Gram negative bacteria. Compound **36d** was found to be active against all the screened bacteria. Photophysical studies were performed on selected fluorescent benzo[*f*]- and benzo[*h*]coumarin and the quantum yields were also calculated. All new compounds were characterized by IR, MS, $^1$H and $^{13}$C NMR, as well as elemental analysis.

*J. Heterocyclic Chem.*, **44**, 1287 (2007).

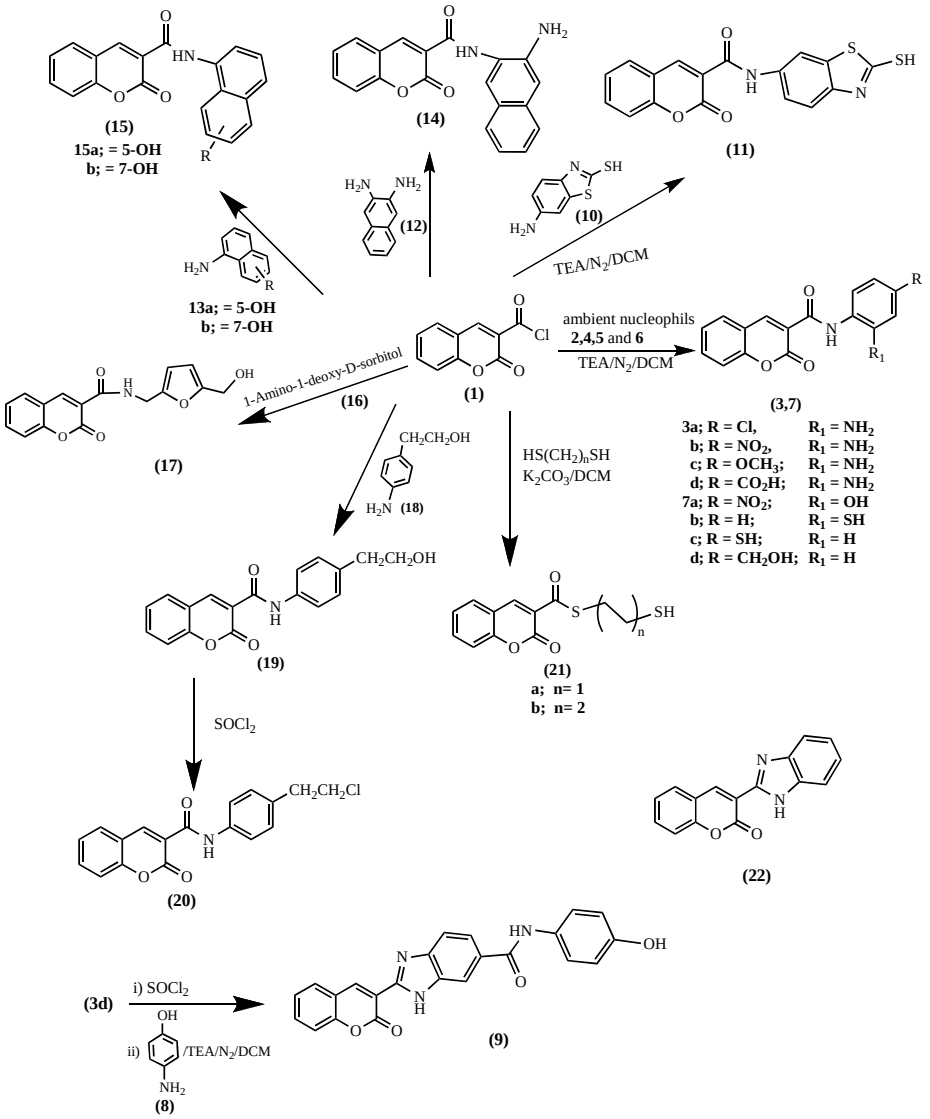
## INTRODUCTION

Coumarin and its derivatives are widely used as additives in food, perfumes, cosmetics, pharmaceuticals, and agrochemicals [1,2]. Coumarins have also been reported to exhibit several biological activities including spasmolytic, antiarrhythmic, cardiothonic, antiviral, and anticancer properties [3]. It is well documented in the literature that coumarin may affect the formation and scavenging of reactive substances derived from oxygen (Reactive Oxygen Species, ROS) as well as influencing the processes involving free radical-mediated injury, as can some other plant phenolics and flavonoids [4,5]. Coumarin and 7-hydroxycoumarin inhibit prostaglandin biosynthesis, which involves fatty acid hydroperoxy intermediates [6]. Various coumarin related derivatives are recognized as inhibitors not only of the lipoxygenase and cyclooxygenase pathways of arachidonate metabolism [7-9] but also of neutrophile dependent superoxide anion generation [10]. There are many synthetic methods to obtain these compounds including Pechmann, Perkin, Knoevenagel, Reformatsky and Wittig reactions [11-15]. However, the Pechmann reaction has been the most widely used for the synthesis of coumarins as it proceeds from very simple starting materials and gives very good yield of 4-substituted coumarins. Several acid catalysts have been used in Pechmann reaction including sulfuric acid [11], aluminum chloride [16], phosphorus pentoxide [17] trifluoroacetic acid [18] and others. Many coumarin derivatives have also been widely used in drugs and biochemistry due to their different bioactivities. These include high emission yield, excellent photostability and extended spectral range. As well, coumarin compounds constitute the largest class of laser dyes in the blue-green region. These types of dyes have been employed as labels for fluorescent energy transfer experiments [19,20]. Recently, we have reported the synthesis of some bioactive heterocyclic compounds [21,22]. In this paper, we report the synthesis, biological evaluation and photophysical studies of some novel coumarin-3-carboxamide and benzocoumarin derivatives.

## RESULTS AND DISCUSSION

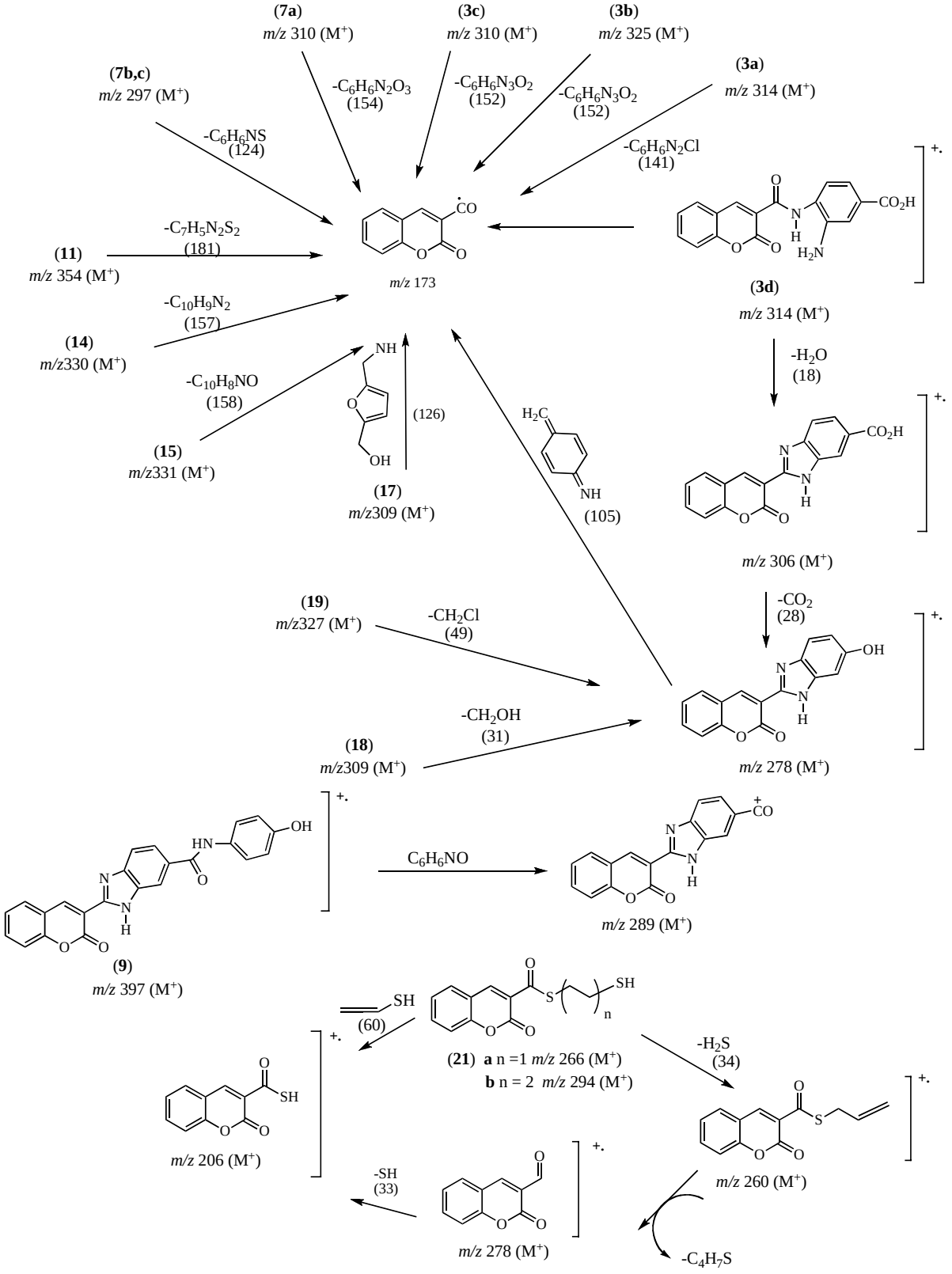
In our attempts to synthesize coumarin derivatives, the reaction of coumarin-3-carbonyl chloride [23-25] (**1**) with ambient nucleophiles such as *o*-phenylenediamine derivatives (**2**) under mild reaction conditions using dichloromethane (DCM)/TEA under $N_2$, a coumarin-3*N*-(2-amino-4-substitutedphenyl)-carboxamide (**3a-d**) was

obtained. Treatment of **1** with 5-nitro-2-aminophenol (**4**), aminothiophenol derivatives (**5**) and 4-hydroxymethylaniline (**6**) yielded the corresponding coumarin-3*N*-(2-hydroxy and/or mercapto-4-substitutedphenyl)-carboxamide (**7a-d**). Reaction of **3d** with $SOCl_2$ afforded acid chloride, which was treated with 4-aminophenol (**8**) in DCM/TEA to obtain a product which was identified as 3-[2-benzimidazol-6-yl-(4-hydroxyphenylcarboxamide)]-coumarin (**9**). Also, **1** was reacted successfully with 6-amino-2-mercaptobenzothiazole (**10**) under the above reaction conditions to afford the corresponding coumarin-3*N*-(2-mercaptobenzo[*d*]thiazol-6-yl)-carboxamide (**11**). Successful reaction of **1** was achieved when potentially bifunctional naphthyl derivatives were used as nucleophiles, thus 2,3-diaminonaphthalene (**12**), 5-amino-1-naphthol and 8-amino-2-naphthol (**13a,b**) reacted with **1** in DCM to furnish the respective amino- and hydroxy coumarin-3*N*-naphthylcarboxamide (**14**, and **15a,b**), respectively. Finally, coumarin-3*N*-(5-hydroxymethylfurfuryl)carboxamide (**17**) was also obtained from the reaction of **1** with 1-amino-1-deoxy-D-sorbitol (**16**) under mild reaction conditions in a nitrogen atmosphere. The formation of **17** indicates that the polyhydroxyamine (**16**) is converted into 5-hydroxymethylfurfurylamine during the reaction, which reacted *in situ* with coumarin-3-carbonyl chloride (**1**). Attempted interaction of **1** with 4-aminophenylethanol (**18**) was also successful and the corresponding coumarin-3*N*-[4-(2-hydroxyethyl)phenyl]carboxamide (**19**) was obtained, which was reacted with $SOCl_2$ to afford the chlorinated derivative as coumarin-3*N*-[4-(2-chloroethyl)phenyl]carboxamide (**20**). Interaction of **1** with ethylene dithiol and/or butan-1,4-dithiol (**20a,b**) in DCM containing $K_2CO_3$ under $N_2$ at room temperature for 24 hrs gave the corresponding coumarin-3-mercaptothioester derivatives (**21a,b**), respectively (Scheme 1).




**Scheme 1**

The proposed structures of the newly prepared compounds (**3, 7, 9, 11, 14, 15, 17** and **19-21**) (Scheme 1) were determined by their IR, $^{1}H$ and $^{13}C$ NMR, studies [26-28]. The structures were further confirmed by mass

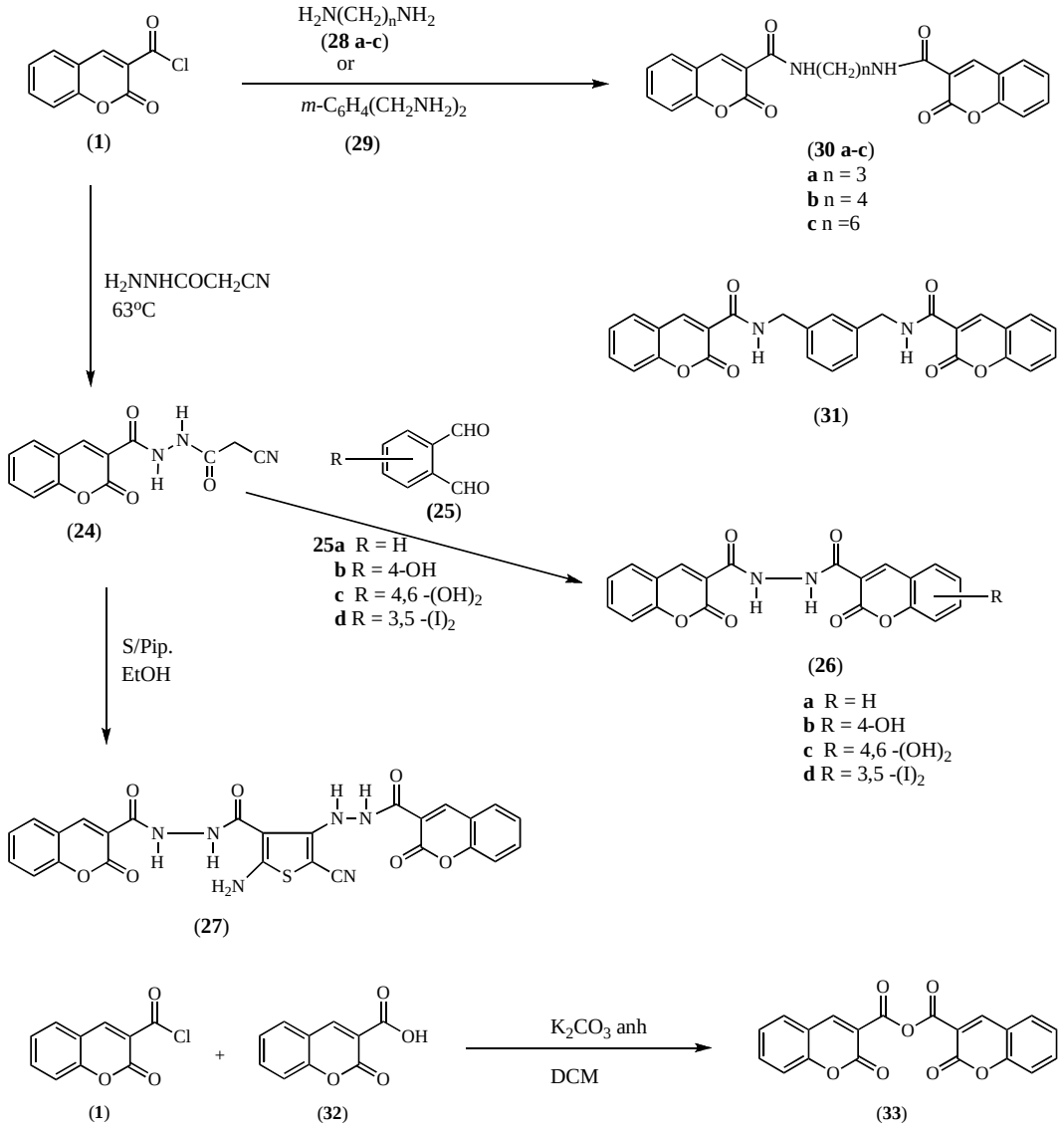



**Scheme 2**

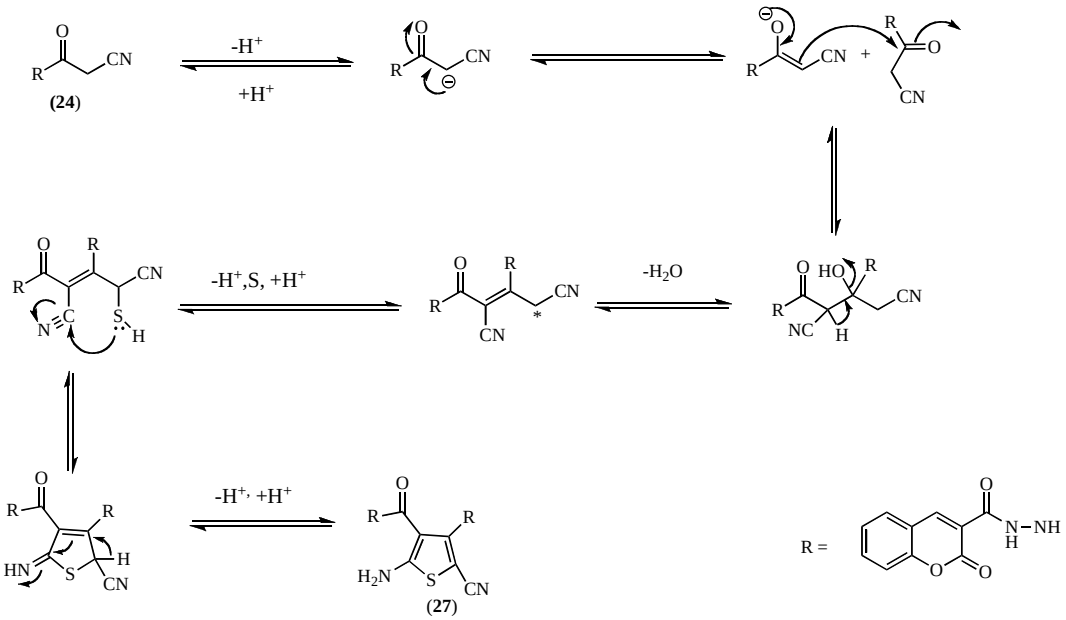
spectroscopic studies. All of the aforementioned compounds showed the base peak at *m/z* (173). This fragment is characteristic for carboxamide type compounds. Based on this, we proposed these structures for these newly synthesized compounds. The mass fragmentations of these compounds led us to rule out the possibility of cyclic structure (**22**) (Scheme 1). The mass fragmentation of coumarin-3*N*-carboxamides (**3-21**) is shown in (Scheme 2).

New double headed coumarin-3*N*-carboxamides were prepared by the interaction of **1** [23-25] with cyanoacetohydrazide (**23**) in DCM/TEA under atmospheric nitrogen at room temperature, the corresponding *N*'-(2-cyanoacetyl)-coumarin-3-carbohydrazide (**24**) was produced. Condensation of **24** with phenolic aldehydes (**25a-d**) in ethanolic piperidine solution [29] yielded the corresponding 1,2-bis-coumarin-3-ylhydrazide (**26a-d**). Treatment of **24** with piperidine in the presence of sulfur flower under the conditions of Gewald [30,31] gave the corresponding coumarin-3-carboxylic acid-*N*-{2-amino-5-cyano-4-[*N*-(coumarin-3-carbonyl)hydrazinocarbonyl]thiophen-2-yl}hydrazide (**27**). Also, in order to procure further double headed coumarin-3*N*-carboxamides, dibasic aliphatic amines were used (*e.g.* 1,3-diaminopropane (**28a**), 1,4-diaminobutane (**28b**), 1,6-diaminohexane (**28c**) and, *m*-xylenediamine (**29**)) to react with coumarin-3-carbonyl chloride (**1**) in DCM under nitrogen at room temperature, which resulted in the formation of the corresponding *N,N*-bis-(coumarin-3-yl)alkylcarboxamides (**30a-c** and **31**) (Scheme 3).

Interaction of coumarin-3-carboxylic acid (**32**) with coumarin-3-carbonyl chloride (**1**) in DCM containing anhydrous $K_2CO_3$ under nitrogen atmosphere gave the corresponding coumarin-3-carboxylic acid anhydride (**33**)




**Scheme 3**




* under the principle of vinylology, the active hydrogen may be one in the γ position of an α, β-unsaturated carbonyl.

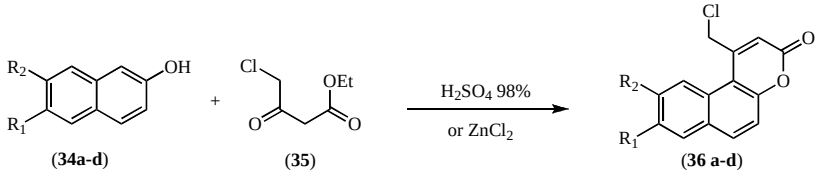
**Scheme 4**

(Scheme 3). The compound **26** may be formed by Knoevenagel type reaction [32-34], while the formation of the thiophene derivatives **27** (Scheme 4) was a sequence consisting of Knoevenagel condensation analogous and subsequent heterocyclization reaction affected by intramolecular attack by thiol on nitrile group; this suggestion was demonstrated by crossover experiment as described in the experimental section. The newly synthesized derivatives were confirmed by spectroscopic evidence. The proposed mechanism for the formation of **27** is presented in (Scheme 4).

The Pechmann-Duisberg [11] reaction was employed to synthesis benzocoumarins. Reaction of β-naphthol (**34a**), 2,7-dihydroxynaphthalene (**34b**), 2,6-dihydroxynaphthalene (**34c**) and 6-bromo-2-naphthol (**34d**) with ethyl 4-chloroacetoacetate (**35**) was performed under Pechmann reaction conditions to synthesize 1-chloromethyl-8/9-substitutedbenzo[*f*]coumarins (**36a-d**) (Scheme 5). Two different condensing agents were used in order to improve the reaction yield: concentrated $H_2SO_4$ (98 %) and anhydrous zinc chloride. The concentrated $H_2SO_4$ was used at room temperature and at 0 °C, while the anhydrous zinc chloride was also used either without solvent (fusion) or in ethanol (95 %). We noticed that a high yield of benzocoumarins was obtained by using concentrated $H_2SO_4$ at 0 °C.

The structure of compounds **36a-d** was confirmed with the aid of spectroscopic data. In the IR spectrum, a sharp absorption at 1688-1737 $cm^{-1}$ indicated the presence of carbonyl functionality. The absorption at 3286 $cm^{-1}$ was assigned to the (OH) vibration for compounds **36b,c**. The $^1H$ NMR spectra had characteristic signals for 1-$CH_2Cl$ at δ 5.29-5.41 and for 2-CH (pyranone proton) at δ 6.79-6.87, while the –OH group appeared at δ 10.19 ppm. The $^{13}C$ NMR spectrum of compound **36b** showed the resonance of 1-$CH_2Cl$ and C=O carbons at δ 46.10 and 159.30, respectively.

Also, 4-chloromethyl-7/8-substitutedbenzo[*h*]coumarins (**38a,b** and **40**) were prepared by Pechmann condensation using 1,5-, and 1,6-dihydroxynaphthalenes (**37a,b**) or 4-chloro-1-naphthol (**39**) (Scheme 6).

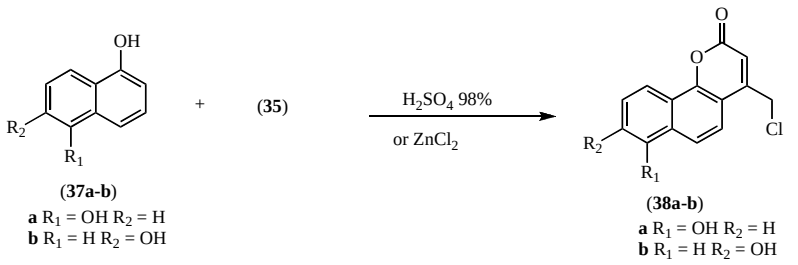


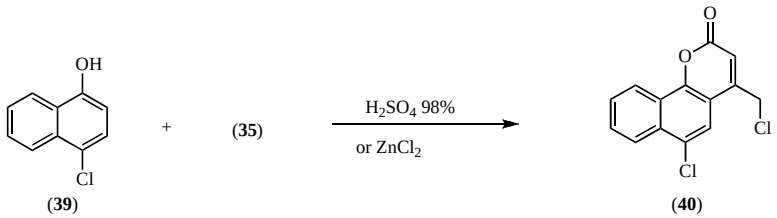

(**34a-d**)
**a** $R_1$ = H $R_2$ = H
**b** $R_1$ = H $R_2$ = OH
**c** $R_1$ = OH $R_2$ = H
**d** $R_1$ = Br $R_2$ =H

(**35**)

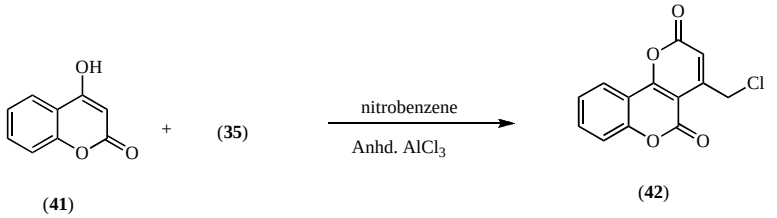
(**36 a-d**)
**a** $R_1$ = H $R_2$ = H
**b** $R_1$ = H $R_2$ = OH
**c** $R_1$ = OH $R_2$ = H
**d** $R_1$ = Br $R_2$ =H

**Scheme 5**




**Scheme 6**




**Scheme 7**

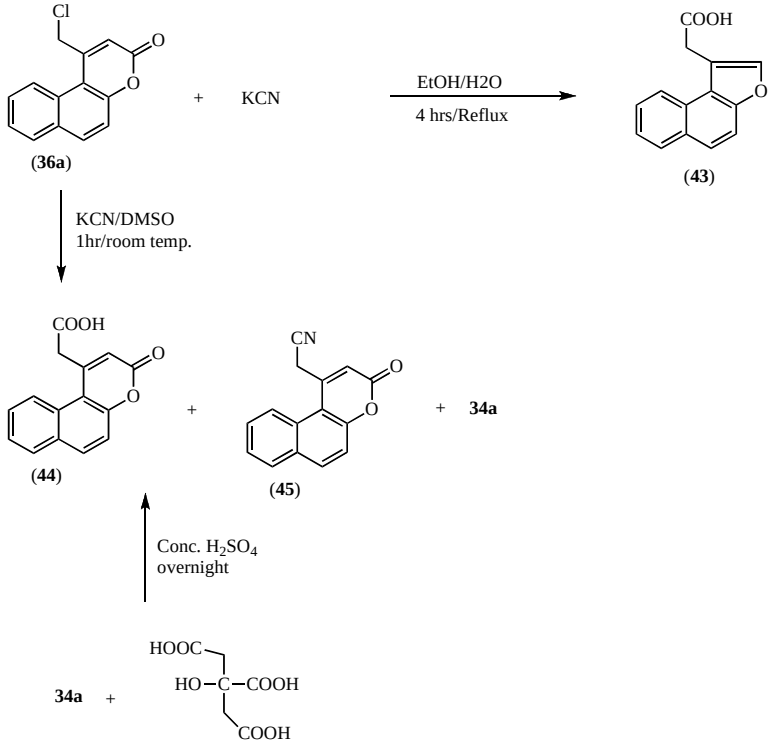
4-Hydroxycoumarin (**41**) has been extensively used as a precursor in the synthesis of heterocyclic compounds [19,35-37]. Condensation of **41** with **35** in the presence of nitrobenzene and anhydrous aluminum chloride afforded the 4-(chloromethyl)-pyrano[3,2-*c*]coumarin-2-one (**42**) (Scheme 7).

Structures of compounds **38a,b, 40** and **42** were determined by spectral data. IR spectra showed absorption bands at 1720-1728 $cm^{-1}$, corresponding to the carbonyl group, while two absorption bands at 1765 and 1729 $cm^{-1}$ were observed in the IR spectra of compound **42** and were recognized as two carbonyl groups. The $^1$H-NMR spectra of these derivatives showed characteristic peaks for 4-$CH_2Cl$, 3-CH (pyranone proton) and –OH at δ 4.24-5.12, 6.65-6.75 and 10.05-10.95 for **38a,b** and **40**, respectively. The $^{13}$C-NMR showed signals for the carbonyl groups at δ 159.74, 159.80 and 159.07 for compounds **38a,b** and **40**, respectively, while compound **42** showed two signals at δ 162.40 and 162.72.

Nitrile compounds are also considered an important precursor in heterocyclic synthesis. Attempts to replace the chlorine atom on the pyranone ring with cyanide group was done to prepare the 2-(benzo[*f*]couamrin-1-yl)acetonitrile as an intermediate that can be used in the synthesis of a variety of five- or fused five-membered as well as six-membered rings. Reaction of potassium cyanide with **36a,b** and **36d** was investigated under different reaction conditions. In the case of **36a**, the reaction was done at refluxing temperature for 4 hours in EtOH/$H_2O$ (1:1). The reaction mixture was then rotary evaporated to produce a clear yellow solution, which gave a white solid on acidification with hydrochloric acid. The white solid was characterized on the basis of its spectral data and mass spectroscopy as 2-(naphtho[2,1-*b*]furan-1-yl)acetic acid (**43**) (Scheme 8). The $^1$H-NMR spectra of compound **43** showed a characteristic peak for the acetic acid methylene group at δ 4.06 instead of δ 5.40 for the chlorormethylene group on the pyranone ring, while the carboxylic proton resonated at δ 12.60. The spectrum also showed a disappearance of the characteristic signal of the 2-CH on the pyranone ring at δ 6.87 and the appearance of another singlet at δ 8.02, corresponding to the 2-CH on the furan ring. In the $^{13}$C-NMR, the acetic acid methylene group resonated at δ 31.38, while the coumarin carbonyl group at δ 159.30 disappeared, and the acetic acid carbonyl group appeared at δ173.00. Mass spectrum of compound **43** showed a molecular ion peak at *m/z* 226 (100%).

Compound **36a** was reacted with KCN in DMSO at room temperature. During workup with water as described in the experimental section, a brownish yellow precipitate separated out which was characterized based

on its spectral data to be 2-(benzo[*f*]coumarin-1-yl)acetonitrile (**45**). On acidification of the filtrate by hydrochloric acid, an off-white solid came out. This solid was washed with ether and the ethereal solution on evaporation gave β-naphthol (**34a**), while the remaining solid was identified as 2-(benzo[*f*]coumarin-1-yl)acetic acid (**44**) that was prepared independently by reaction of β-naphthol (**34a**) with acetone dicarboxylic acid, which was formed *in situ* from a mixture of citric acid (**46**) and concentrated sulfuric acid (Scheme 8).



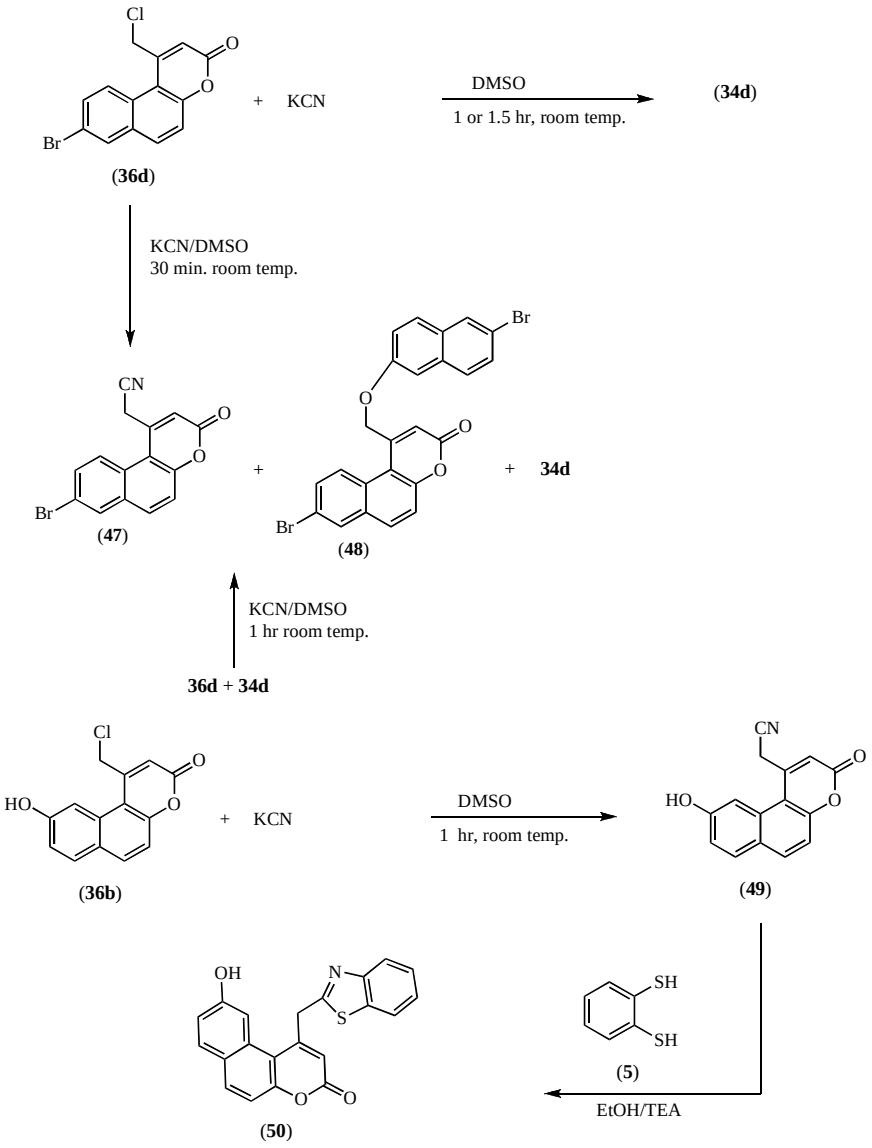

**Scheme 8**

The [1]H-NMR analysis of compound **44** showed a characteristic peak for the methylene group at δ 4.35, while the 2-CH (pyranone proton) resonated at δ 6.61. The [13]C-NMR showed the methylene group at δ 42.91, with an additional signal for the carboxylic group at δ 171.08. The structure of compound **45** was established by its mass spectra while a molecular ion peak appeared at *m/z* 235 (81 %) and the base peak at *m/z* 207 (100 %) ($M^+$-CO).

The reaction between **36d** and KCN in DMSO as medium was done at different reaction times, 1.5 hours, 1 hour and 30 minutes. The first two reaction times (1.5 and 1 hr.) resulted in the formation of 6-bromo-2-naphthol (**34d**) as the only isolable product, where complete dissociation of the pyranone ring occurred. For the third reaction time (30 minute) two reaction products were obtained in the form of 2-(8-bromobenzo[*f*]coumarin-1-yl)acetonitrile (**47**) and 8-bromo-1-((naphthalen-2-yloxy)-methyl)benzo[*f*]coumarin (**48**) along with **34d** as the major one (Scheme 9). Compound **48** was also independently prepared by reaction of **36d** with **34d** in DMSO/$K_2CO_3$ for 1 hour at room temperature (Scheme 9).

Treatment of **36b** with KCN in DMSO for 1 hour afforded the corresponding 2-(9-hydroxybenzo[*f*]coumarin-1-yl)acetonitrile (**49**) as a product (Scheme 9). The formation of such nitrile derivative (**49**) prompted us to use the cyano group for the synthesis of benzothiazol derivative. Thus treatment of **49** with 2-aminothiophenol (**5**) in ethanol/TEA solution, resulted in the formation of 1-((benzo[*d*]thiazol-2-yl)methyl)-9-hydroxybenzo[*f*]coumarin (**50**) through a nucleophilic addition of the thiol group to the cyano group, which was then followed by intramolecular cyclization with elimination of an ammonia molecule. The formation of compound **50** can be considered as an example of methylene bridge-head heterocycle-containing benzo[*f*]coumarin.

Structure of compound **47** was confirmed by mass spectroscopy while the molecular ion peak appeared at *m/z* 314 (15 %) together with $M^+$+2 (13 %). The [1]H-NMR spectra for compounds **48** showed signals at δ 5.86 corresponding to the methylene group, while the 2-CH (pyranone proton) peak appeared at δ 6.88. The methylene group in compound **49** resonated at higher field at δ 4.78. The [13]C-NMR spectra for **49** showed signal at δ 117.26, which corresponded to cyanide functionality and the

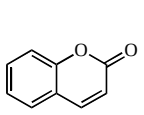



**Scheme 9**

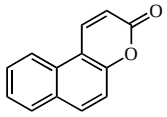
methylene group appeared at δ 25.84. Also, structure of compound **50** was established by mass spectroscopy which showed the molecular ion peak at *m/z* 359 (13 %).

**Photophysical Studies** (**Table 1**). Coumarin derivatives exhibiting the basic 1-ring structure (**A**) normally presents fluorescence quantum yields ranging from 0.10 to 0.70 [36-38]. However, lower quantum yields have been reported in the literature since coumarin is a good photosensitizer [39]. In that respect, inter and intramolecular energy transfer systems where the donor fragment (coumarin) exhibited lower intensity fluorescence have also been investigated [39-41]. In addition, photoinduced electron transfers in donor-acceptor dyads were reported as well, all rendering the fluorescence quantum yield lower [42]. However, lower quantum yields could also be measured for different

**Table (1):** Quantum yield (in reference to 9,10-diphenylanthracene) in 2-methyl-tetrahydrofuran, and wavelength of excitation for the calculated quantum yield.[a)]



(**A**)



(**B**)

| Compound | $\Phi_F$ | $\lambda_{exc}$ |
|---|---|---|
| **36b** | 0.011 | 368 |
| **36c** | 0.016 | 370 |
| **36d** | 0.018 | 366 |
| **38a** | 0.068 | 370 |
| **38b** | 0.055 | 370 |
| **40** | 0.027 | 366 |
| **44** | 0.047 | 352 |

a) The uncertainty on $\Phi_F$ is 10 %.

solvents depending on the substituent, and so this chromophore appears sensitive to its environment [43]. For coumarin with two fused rings (*i.e.* benzocoumarin; up right structure **B**), fluorescence quantum yields are generally somewhat lower than the 1-ring counter part (coumarins), ranging from 0.02 to 0.16 [34,35].

The compounds **36b-d**, **38a**, **38b**, **40**, and **44** make no exception (Figure 1). Their fluorescence quantum yields fall exactly in that range, although in some cases where lower values are measured (< 0.02), this could be explained by the presence of a heavy atom (Cl and Br) and a loose arm ($CH_2Cl$) which can decrease the radiative rate constant by spin-orbit coupling and "loose bolt effect" [44]. It is intuitively anticipated that the Br-derivative (**36d**) should exhibit a lower quantum yield (owing to the presence of 2 heavy atom instead of 1), but the "loose bolt effect" and perhaps deactivation by collisions of the flexible $CH_2Cl$ arm onto the adjacent aromatic ring may be the dominant in this series (**36a-d**), and so the quantum yields are all similar. A proof to this explanation is found in the comparison between **36b-d** with **44**, where the main difference is the replacement of the $-CH_2Cl$ group by $-CH_2CO_2H$. The latter is also a flexible arm but does not exhibit the Cl heavy atom. Nonetheless, the coumarin skeleton structure plays a definite role, whether the O-atom is connected at the α- or β-position of the naphthalene aromatic (see 36b-d vs 38a,b and 40). The quantum yields for the formers are larger. No explanation can be given at this moment.

All in all, the reported coumarin exhibits reasonable to good fluorescence quantum yield for potential applications in sensing, laser and related photonic devices. The presence of Cl-leaving groups makes them interesting precursors for their anchoring on other fragments such as solid support and polymers. Once the Cl-leaving group is replaced (by a light atom), the quantum yield should become high again, making it interesting for applications.

**Antibacterial Activity.** Antibacterial bioassay on newly synthesized compounds was performed. Only four of these compounds (**36, 36c, 40** and **44**) exhibited weak bioactivity against eight different bacteria, *Staphylococcus aureus, Pseudomonas aeruginosa, Entrococcus faecalis, Escherischia coli, Besillus cerus, Staphylococcus agalactiae, Comeybacterium xerosis* and *Staphylococcus epidermidis*. The antibacterial activity data suggested to us that bioactivity was not significant and based on this we did not compare this bioactivity with standard antibiotics. The antibacterial activity data is presented in (Table 2).

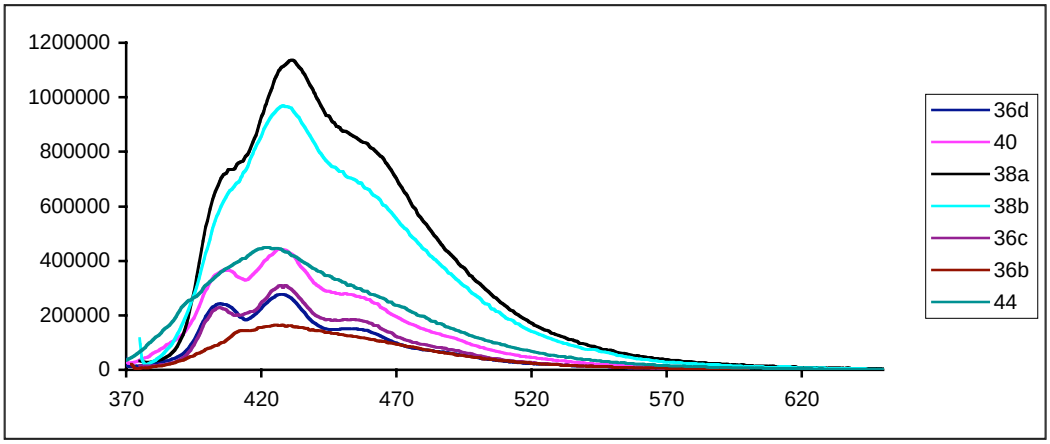



**Figure** (**1**): Fluorescence spectra recorded for the benzocoumarin derivatives in 2-methyltetrahydro furan, and at room temperature.

**Table** (**2**): Antimicrobial activity of some compounds

| Compd. | *S. aureus* | *Ps. Aeruginosa* | *E. faecalis* | *E. coli* | *B. cerus* | *S. agalactiae* | *C. xerosis* | *S. epidermidis* |
|---|---|---|---|---|---|---|---|---|
| | Diameter of zone of inhibition in mm | | | | | | | |
| **36c** | 7.0 | 0 | 0 | 0 | 6.7 | 0 | 6.7 | 0 |
| | 7.0 | 0 | 0 | 0 | 7.0 | 0 | 6.7 | 0 |
| | 7.0 | | | | 6.85 | | 6.7 | |
| **36d** | 14.0 | 6.5 | 9.0 | 11.0 | 18.5 | 14.5 | 14.0 | 16.0 |
| | 14.5 | 6.5 | 9.0 | 11.0 | 18.0 | 15.0 | 14.5 | 16.0 |
| | 14.25 | 6.5 | 9.0 | 11.0 | 18.25 | 14.75 | 14.25 | 16.0 |
| **40** | 8.0 | 0 | 14.0 | 0 | 12.0 | 10.0 | 11.0 | 16.5 |
| | 8.5 | 0 | 13.8 | 0 | 12.0 | 10.2 | 11.0 | 16.3 |
| | 8.25 | | 13.9 | | 12.0 | 10.1 | 11.0 | 16.4 |
| **44** | 0 | 0 | 0 | 0 | 11.0 | 0 | 7.0 | 0 |
| | 0 | 0 | 0 | 0 | 11.5 | 0 | 7.5 | 0 |
| | | | | | 11.25 | | 7.25 | |

## EXPERIMENTAL

Melting points were measured in open capillary tubes and are uncorrected. $^1H$ and $^{13}C$ NMR were recorded at 200 and 50 MHz respectively, on Varian Gwmini 200 spectrometer, in DMSO-$d_6$, with chemical shifts being calculated from the solvent. C NMR spectra were obtained by using an attached proton test (APT). With this technique, the signal for carbon atom bearing an even number of protons appears normal. Mass spectra were reported on Hewlett Packard 5989 B Mass spectrometer. IR spectra were recorded on Bomem MB-Series FT-IR spectrometer (KBr pellet).

**Synthesis of Coumarin-3*N*-carboxamides (3-17).**

**General Method.** To a well stirred solution of **1** (0.208 g, 1 mmol) in dry DCM containing a few drops of TEA was added an equivalent amount of an ambient nucleophile (1.2 mmol). The reaction mixture was stirred at ambient temperature under dry conditions in the presence of $N_2$ for 3 hours. The DCM was removed under reduced pressure till dryness, the obtained solid was then washed with 10 % HCl and the remaining solid was recrystallized using benzene or ethanol as solvents. *N-(*2-amino-4-chlorophenyl)-2-oxo-2H-chromene-3-carboxamide

***N*-(2-Amino-4-chlorophenyl)-2-oxo-2*H*-chromene-3-carboxamide 3a.** Yellowish-green (0.309 g, 95.50 %) m.p. 312-4 °C; IR (KBr disc): 1716, 1668 (CO), 3117, 3178, 3220 (NH).; PMR (DMSO-$d_6$): δ 6.82-9.05 (9H, m, Ar-H, $NH_2$), 10.00 (1H, s, H-4), 11.07 (1H, Hump, NHCO, cancelled by $D_2O$),; Ms (%): *m/z* 314 [$M^+$], 173 (100); $C_{16}H_{11}ClN_2O_3$ (314.73); Cal.: C, 61.06; H, 3.52; N, 8.90; Found: C, 61.14; H, 3.49; N, 8.83.

***N*-(2-Amino-4-nitrophenyl)-2-oxo-2*H*-chromene-3-carboxamide 3b.** Light yellow (0.15g, 46.15%) m.p. 319-21°C; IR (KBr disc): 1717 (CO), 3111, 3184, 3222 (NH), 3050 (Ar-H).; PMR (DMSO-$d_6$): δ (7.34-7.55), (7.75-7.84), (8.02-8.07) (9H, set of multiplets, Ar-H, $NH_2$), 9.01, 9.02 (1H, speleted singlet, H-4), 10.71 (1H, hump, NH).; Ms (%): *m/z* 325 [$M^+$], 173 (100); $C_{16}H_{11}N_3O_5$ (325.28); Cal.: C,59.08; H, 3.41; N, 12.92; Found: C, 59.25; H, 3.35; N, 12.99.

***N*-(2-Amino-4-methoxyphenyl)-2-oxo-2*H*-chromene-3-carboxamide 3c.** Brownish-yellow crystals (0.25g, 80.60%) m.p. 304-5°C; IR (KBr disc): 1713 (CO), 3287 (NH), 3062 (Ar-H).; PMR (DMSO-$d_6$): δ 3.80 (3H, s, $OCH_3$), 6.87 (2H, sbr, $NH_2$), 7.45-8.02 (7H, m, Ar-H), 9.00 (1H, s, H-4), 10.68 (1H, s, NH).; Ms (%): *m/z* 310 [$M^+$], 173 (100); $C_{17}H_{14}N_2O_4$ (310.30); Cal.: C, 65.80; H, 4.55; N, 9.03; Found: C, 65.91; H, 4.67; N, 9.15.

**3-Amino-4-(2-oxo-2*H*-chromene-3-carboxamido)benzoic acid (3d).** Greenish (0.30g, 92.59%) m.p. 320°C dec.; IR (KBr disc): 1716 (CO), 3238 (OH, NH).; PMR (DMSO-$d_6$): δ 7.49-8.27 (7H, m, Ar-H), 8.92 (1H, s, H-4), 9.01, 9.05 (3H, 2s, $NH_2$, NH, cancelled by $D_2O$), 13.29 (1H, s, COOH, cancelled by $D_2O$).; Ms (%): *m/z* 324 [$M^+$], 306 (31), 278 (4), 173 (100), 159 (30), 101 (19), 44 (17);$C_{17}H_{12}N_2O_5$ (324.29); Cal.: C, 62.96; H, 3.73; N, 8.64; Found: C, 63.08; H, 3.79; N, 8.72.

***N*-(2-Hydroxy-4-nitroxyphenyl)-2-oxo-2*H*-chromene-3-carboxamide 7a**. Colorless crystals (0.30 g, 92.02%) m.p. 284-5°C; IR (KBr disc): 1783, 1702 (CO), 3137 (OH, NH, br).; PMR (DMSO-$d_6$): δ 6.99-7.99 (6H, m, Ar-H), 8.98 (1H, s, H-4), 9.24 (1H, s, H-3), 11.21 (1H, s, NH), 11.98 (1H, br, OH).; Ms (%): *m/z* 326 [$M^+$] (11), 173 (100), 145 (3); $C_{16}H_{10}N_2O_6$ (326.26);Cal.: C, 58.90; H, 3.09; N, 8.59; Found: C, 58.92; H, 3.11; N, 8.60.

***N*-(2-Mercaptophenyl)-2-oxo-2*H*-chromene-3-carboxamide 7b.** Yellow crystals (0.23g, 84.18%) m.p. 304°C; IR (KBr disc): 1712 (CO), 3202 (NH).; PMR (DMSO-$d_6$): δ 7.00-8.50 (8H, m, Ar-H), 9.00 (1H, s, H-4), 11.35 (1H, s, NH).; Ms (%): *m/z* 297 [$M^+$], 173 (100); $C_{16}H_{11}NO_3S$(297.33);Cal.: C, 64.63;H, 3.73; N, 4.71; Found: C, 64.80; H, 3.71; N, 4.60.

***N*-(4-Mercaptophenyl)-2-oxo-2*H*-chromene-3-carboxamide 7c.** Yellow crystals (0.25g, 77.5%) m.p. 256-8°C; IR (KBr disc): 1700 (CO), 2550 (SH), 3263 (NH).; Ms (%): *m/z* 297 [$M^+$, 43], 173 (100), 152 (4), 101 (17), 89 (11), 58 (6), 43 (27); $C_{16}H_{11}NO_3S$(297.33);Cal.: C, 64.63;H, 3.73; N, 4.71; Found: C, 64.75; H, 3.79; N, 4.83.

***N*-(4-(Hydroxymethyl)phenyl)-2-oxo-2*H*-chromene-3-carboxamide 7d.** Yellow crystals m. p. 300°C, IR (KBr disc): 1710 (CO), 3247 (NH).;PMR (DMSO-$d_6$): δ 2.31 (3H, s, $CH_3$), 4.47 (2H, s, $CH_2$), 7.02-8.13 (7H, m, Ar-H), 9.02 (1H, s, H-4), 10.64 (1H, s, NH, cancelled by $D_2O$).

***N*-(2-Mercaptobenzo[*d*]thiazol-5-yl)-2-oxo-2*H*-chromene-3-carboxamide (11).** Yellow crystals (0.30g, 84.75%) m.p. 348-50°C; IR (KBr disc): 1700 (CO, br), 3214 (NH), 3029, 3043 (Ar-H).; Ms (%): *m/z* 354 [$M^+$, 32], 322 (3), 173 (100), 145 (4); $C_{17}H_{10}N_2O_3S_2$ (354.40); Cal.: C, 57.61;H, 2.84;N, 7.90; Found: C, 57.62; H, 2.82; N, 7.88.

***N*-(3-Aminonaphthalen-2-yl)-2-oxo-2*H*-chromene-3-carboxamide (14).** Yellow needles (0.30g, 90.90%) m.p. 355-7°C; IR (KBr disc): 1704 (CO), 3220, 3184 ($NH_2$), 3050 (Ar-H).; PMR (DMSO-$d_6$): δ 7.44-8.05 (8H, m Ar-H), 8.44 (2H, s, H-1, 4), 9.02 (1H, s, H-4), 10.78 (1H, sbr, NH).; Ms (%): *m/z* 330 [$M^+$], 173 (100); $C_{20}H_{14}N_2O_3$ (330.34);Cal.: C, 72.72;H, 4.27; N, 8.48; Found: C, 72.85; H, 4.38; N, 8.60.

***N*-(5-Hydroxynaphthalen-1-yl)-2-oxo-2*H*-chromene-3-carboxamide (15a).** Deep red crystals (0.24g, 72.81%) m.p. 265-7°C; IR (KBr disc): 1715, 1652 (CO), 3347, 3220 (OH, NH).; PMR (DMSO-$d_6$): δ 5 set of multiplets (6.93-6.97), (7,40-7.57), (7.73-7.82), (7.98-8.05), (8.30-8.34), (10H, m, Ar-H), 9.04 (1H, s, H-4), 10.31 (1H, s, NH), 11.24 (1H, s, OH).; CMR (DMSO-$d_6$): δ 161.56, 159.57, 153.84, 132.42, 126.95, 125.19, 118.92, 118.54, 148.24, 134.40, 130.42, 127.14, 125.30, 124.22, 118.98, 118.45, 116.20, 110.82, 108.49.; Ms (%): *m/z* 331 [$M^+$, 45], 173 (100), 158 (2), 145 (5); $C_{20}H_{13}NO_4$ (331.32); Cal.: C, 72.50; H, 3.95; N, 4.23; Found: C, 72.70; H, 3.90; N, 4.29.

***N*-(7-Hydroxynaphthalen-1-yl)-2-oxo-2*H*-chromene-3-carboxamide (15b).** Orange yellow needles (0.29g, 87.61%) m.p. 232-3°C; IR (KBr disc): 1700 (CO), 3293 (OH, NH, br), 3050 (Ar-H).; PMR (DMSO-$d_6$): δ 7.14-8.20 (10H, complex pattern, Ar-H), 9.05 (1H, s, H-4), 10.05 (1H, s, NH), 11.05 (1H, s, OH).; CMR (DMSO-$d_6$): δ 161.51, 159.79, 156.08, 153.96, 131.14, 128.34, 127.65, 119.20, 118.60, 148.24, 134.50, 130.50, 130.38, 125.40, 125.06, 122.03, 119.27, 118.67, 116.31, 102.56.; Ms (%): *m/z* 331 [$M^+$, 42], 173 (100), 158 (6), 145 (4), 101 (20); $C_{20}H_{13}NO_4$ (331.32); Cal.: C, 72.50; H, 3.95; N, 4.23; Found: C, 72.68; H, 4.01; N, 4.29.

***N*-((5-(Hydroxymethyl)furan-2-yl)methyl)-2-oxo-2*H*-chromene-3-carboxamide17.** Colorless crystals (0.28g, 87.54%) m.p. 78-9°C; IR (KBr disc): 1712 (CO), 3451, 3397, 3111, (OH, NH), 3038 (Ar-H), 2946 (CH-aliph.).; PMR (DMSO-$d_6$): δ 3.82 (2H, s, $CH_2NH$), 4.23 (1H, t, $CH_2OH$, J = 7 Hz), 7.36-7.92 (6H, m, Ar-H), 8.74 (1H, s, H-4), 8.77 (1H, s, NH).; CMR (DMSO-$d_6$): δ 162.55, 155.94, 154.49, 117.76, 117.66, 117.34, 61.19, 56.47, 116.11, 124.80, 130.23, 134.44, 134.53, 148.60, 148.97.; Ms (%): *m/z* 298 [$M^+$ - H, 15], 281 (18), 173 (100), 118 (2), 101 (28), 89 (22), 63 (11); $C_{16}H_{13}NO_5$ (299.28);Cal.: C, 64.21; H, 4.38; N, 4.68; Found: C, 64.12; H, 4.30; N, 4.60.

***N*-(4-(2-Hydroxyethyl)phenyl)-2-oxo-2*H*-chromene-3-carboxamide (19).** Yellow needles (0.29g, 95.08%) m.p. 187-8°C; IR (KBr disc): 1704, 1718 (CO), 3287 (OH, NH), 3056 (Ar-H),

2928, 2861 (CH-aliph.).; PMR (DMSO-$d_6$): δ 7.19-8.01 (8H, m, Ar-H), 8.90 (1H, s, H-4), 2.69 (2H, t, $CH_2Ar$), 3.55 (2H, t, $CH_2OH$, J = 7 Hz), 4.36 (1H, hump., OH).; Ms (%): *m/z* 309 [$M^+$, 28], 278 (65), 173 (100), 89 (24); $C_{18}H_{15}NO_4$(309.32); Cal.: C, 69.86; H, 4.89; N, 4.53; Found: C, 69.95; H, 4.98; N, 4.69.

***N*-(4-Hydroxyphenyl)-2-(2-oxo-2*H*-chromene-3-yl)-3*H*-benzo-[*d*]imidazole-5-carboxamide (9).** *N*-(2-Amino-4-carboxy-phenyl)coumarin-3-carboxamide (**3d**) (0.324 g, 1 mmol) in 10 mL thionyl chloride was stirred at 80-100 °C under dry reaction conditions in the presence of $N_2$ for 4 hours. The excess thionyl chloride was removed under reduced pressure, and the obtained dry acid chloride was dissolved in dry DCM and treated with an equivalent amount of 4-aminophenol in the presence of a few drops of TEA, and the reaction mixture was stirred at room temperature for 1 hour. The solvent was evaporated under reduced pressure and the obtained solid was recrystallized using benzene as solvent to afford brownish red crystals (0.24 g, 60.5 %), m.p. 270 °C; IR (KBr disc): 3269 (OH), 1714 (CO); PMR (DMSO-$d_6$): δ 6.74, 7.55 (4H, 2d, J = 8.4 Hz, Ar-H), (7.44-7.47), (7.72-8.05) (6H, complex potteren, Ar-H), 8.28 (1H, s, Ar-H), 9.21 (1H, s, H-4), 10.08 (1H, s, OH; cancelled with $D_2O$), 10.63 and 10.93 (2H, 2s, NH; cancelled with $D_2O$) ppm. Ms: *m/z* 397 ($M^+$), 289 (100 %) ($M^+$ - $C_6H_6ON$).

***N*-(4-(2-Chloroethyl)phenyl)-2-oxo-2*H*-chromene-3-carbox-amide (20).** N-(4-(2-Hydroxyethyl)phenyl)coumarin-3-carboxamide (**19**) (0.31 g; 1 mmol) in 15 mL $SOCl_2$ under $N_2$ atmosphere was stirred at 70 °C for 1 h. The excess thionyl chloride was removed under reduced pressure, and the solid obtained was recrystallized in ethanol as golden yellow needles (0.29 g; 93.9 %) m.p. 175-8 °C; IR (KBr disc): 3220 (NH), 3050 (Ar-H), 2916, 2861 (aliph. C-H) and 1701 (CO); PMR (DMSO-$d_6$): δ 2.80 (2H, t, Ar-$CH_2$), 3.63 (2H, t, $CH_2Cl$), 7.55, 7.80 (4H, AB-q, J = 7.80 Hz, Ar-H), 10.39 (1H, s, NH), 8.70 (1H, s, H-4), 6.99-7.47 (4H, m, Ar-H) ppm; CMR (DMSO-$d_6$): δ 40.74 (Ar-$CH_2$), 62.14 ($CH_2Cl$), 153.9 (CONH), 160 (COO), 135.8, 135.6, 118.5, 116.2, 119.8, 125.3, 129.4, 130.3, 134.3 and 147.4 ppm. Ms: *m/z* 327 ($M^+$) (9 %), 279 (14 %), 278 (65 %), 173 (100 %), 145 (5 %), 101 (29 %), 89 (25 %), 63 (10 %) and 43 (8); $C_{18}H_{14}NO_5$ (327.77); Cal.: C, 65.96; H, 4.31; N, 4.68; Found: C, 66.04; H, 4.29; N, 4.60.

**Coumarin-3-mercaptothioesters (21a,b).** To a well stirred solution of **1** (0,5 g; 2.4 mmol), was added the respective dithiols solution (2.4 mmol) in dry DCM (10 mL) and $K_2CO_3$ anhydrous 1 g under nitrogen dropwise for 1/2 hour and the stirring was continued for 24 hours at room temperature. The reaction mixture was filtered to remove the excess $K_2CO_3$ and evaporated DCM under reduced pressure to obtain the corresponding mercaptothioester.

***S*-2-Mercaptoethyl 2-oxo-2*H*-chromene-3-carbothioate (21a).** Yellow crystals (0.30g, 47.00%) melt at 155 °C then solidified again and remelted at 275 °C; IR (KBr disc): 3050 (Ar-H), 2922, 2855 ($CH_2$), 2557 (SH), 1718, 1639 (CO) $cm^{-1}$. PMR (DMSO-$d_6$): δ 2.68 (2H, t, $CH_2SH$, J = 7.43 Hz), 3.25 (2H, t, $CH_2SO$, J = 7.43 Hz), 3 set of multiplets at 7.40, 7.74, 7.89 (4H, m, Ar-H), 8.68 (1H, s, H-4) ppm; CMR (DMSO-$d_6$): δ 23.40, 32.70, 116.20, 125.10, 131.10, 135.00,187.10, 116.10, 117.90, 122.30, 157.50 ppm.; Ms (%): *m/z* 266 ($M^+$, 0 %), 206 ([$M^+$ - HSCH=$CH_2$], 17 %), 173 ($M^+$ - [$SCH_2CH_2SH$], 100 %), 145 ($M^+$ - [$COSCH_2CH_2SH$], 7 %); $C_{12}H_{10}S_2O_3$ (266.34);Cal.: C, 54.12; H, 3.78; Found: C, 54.19; H, 3.87.

***S*-4-Mercaptobutyl 2-oxo-2*H*-chromene-3-carbothioate (21b).** Pale yellow crystals (0.34 g, 48 %)m.p. 92 °C; IR (KBr disc): 3043 (Ar-H), 2970, 2928, 2855 (aliph. CH), 2563 (SH), 1729 (CO).; PMR (DMSO-$d_6$): δ 1.73 (m , 4H, $(CH_2)_2$), 2.27, 2.32 (2H, 2d, $CH_2S$, J = 7 Hz), 2.98 (2H, t, $CH_2S$; J = 7 Hz), 7.38-7.48 (2H, m, Ar-H), 7.73, 7.76, 7.80 (1H, 2d, Ar-H, J = 1.6 Hz), 7.96, 8.00 (2H, dd, Ar-H, J = 8, 1.2 Hz), 8.76 (1H, s, H-4) ppm.; PMR (DMSO-$d_6$): δ 28.15, 32.49, 56.44, 58.25, 117.91, 122. 54, 154.28, 157.39, 187.35, 116.15, 125.02, 130.95, 134.83, 146.46.; Ms (%): *m/z* 294 ([$M^+$], 1 %), 260 ([$M^+$ - $H_2S$], 1 %), 173 ([$M^+$ - $H_2S$, $C_4H_7S$], 100 %), 145 ([$M^+$ - $H_2S$, $C_4H_7S$, CO], 3 %); $C_{14}H_{14}SO_3$(294.39); Cal.: C, 57.12; H, 4.79; Found: C, 57.23; H, 4.90.

***N*'-(2-Cyanoacetyl)-2-oxo-2*H*-chromene-3-carbohydrazide (24).** A solution of coumarin-3-carbonylchloride (**1**) (2.08 g, 10 mmol) in 20 mL DCM containing few drops of piperidine was treated and stirred at room temperature with a solution of cyanoacetohydrazide (**23**) (1.19 g, 12 mmol) in 10 mL DCM under nitrogen and the mixture was left standing for 4 h. The DCM was removed under reduced pressure till dryness, the obtained solid was recrystallized from glacial acetic acid as white crystals (2.4 g, 88.56 %) m.p. 254-5 °C; IR (KBr disc): 1700, 1653 (broad band CO), 2259 (CN), 2977, 2932 (aliph. CH), 3220, 3299 (NH).; PMR (DMSO-$d_6$): δ 3.82 (2H, s, $CH_2CN(CO)$, 7.40-7.98 (4H, m, Ar-H), 8.87 (1H, s, H-4), 10.62, 11.03 (2H, 2s, 2NHCO) ppm.; CMR (DMSO-$d_6$): δ 168.49, 165.10, 161.00, 149.40, 148.70, 129.42, 120.60, 119.30, 118.77, 113.73, 96.68, 19.34.; Ms (%): *m/z* 271 ([$M^+$], 4 %), 204 (1 %), 173 (100 %), 145 (3 %), 118 (2 %), 101 (19 %), 89 (16 %), 63 (9 %), 44 (8 %); $C_{13}H_9N_3O_4$ (271.23); Cal.: C, 57.57; H, 3.34; N, 15.49; Found: C, 57.80; H, 3.46; N, 15.51.

*Condensation of (24) with phenolic aldehydes (25).*

**General Method.** A solution of **24** (0.16 g, 0.6 mmol) in 20 mL absolute ethanol and few drops of piperidine was treated with respective phenolic aldehyde (0.16 mmol) and the reaction mixture was stirred under reflux for 30 minutes, the solid precipitate was filtered as a crystals which were insoluble in most organic solvents.

***N,N*-Bis-(coumarin-3-yl)hydrazide (26a).** Brownish yellow crystals (0.18 g, 79.79 %) m.p. > 360 °C; IR (KBr disc): 3266 (NH), 3050 (Ar-H), 1700, 1653 (CO).; Ms (%): *m/z* 376 ([$M^+$], 16), 173 (100), 145 (6), 118 (5), 101 (20), 63 (8), 51 (4); $C_{20}H_{12}N_2O_6$ (376.32); Cal.: C, 63.83; H, 3.21; N, 7.44; Found: C, 63.84; H, 3.22; N, 7.46.

**Coumarin-3-carboxylic acid-*N*-(7-hydroxycoumarin)-3-carbonylhydrazide (26b).** Light brownish crystals (0.19 g, 80.78 %) m.p. > 360 °C, IR (KBr disc): 3263 (NH), 3050 (Ar-H), 1701 (CO).; Ms (%): *m/z* 392 ([$M^+$], 0), 377 (4), 376 (16), 204 (2), 203 (1), 189 (3), 174 (11), 173 (100), 145 (3), 101 (12), 89 (9), 44 (3); $C_{20}H_{12}N_2O_7$ (392.32); Cal.: C, 61.23; H, 3.08; N, 7.14; Found: C, 61.41; H, 3.16; N, 7.32.

**Coumarin-3-carboxylic acid-*N*-(5,7-dihydroxycoumarin)-3-carbonylhydrazide (26c).** Brownish red crystals (0.15 g, 61.27 %) m.p. > 360 °C; IR (KBr disc): 1700 (CO, broad), 3299-3232 (NH, OH).; Ms (%): *m/z* 408 ([$M^+$], 0), 376 (12), 204 (2), 189 (2), 173 (100), 145 (3), 118 (3), 101 (20), 89 (14), 63 (7), 44 (14); $C_{20}H_{12}O_8N_2$ (408); Cal.: C, 58.83; H, 2.96; N, 6.86; Found: C, 58.70; H, 2.91; N, 6.94.

**Coumarin-3-carboxylic acid-*N*-(6,8-dihydroxycoumarin)-3-carbonylhydrazide (26d).** Orange crystals (0.21 g, 55.7 %) m.p. 275-7 (dec.) °C; IR (KBr disc): 3296, 3257 (NH), 3050 (Ar-H), 1717, 1682 (CO); Ms (%): *m*/z 627 ([$M^+$ - 1], 15), 423 (66), 395 (16), 297 (5), 268 (16), 240 (15), 204 (29), 173 (100),

128 (14), 127 (11); $C_{20}H_{10}N_2O_6I_2$ (627.31); Cal.: C, 38.29; H, 1.61; N, 4.47; Found: C, 38.21; H, 1.54; N, 4.55.

*Interaction of (24) with sulfur under Gewald conditions: coumarin-3-carboxylic acid-*N*-{5-amino-2-cyano-4-[*N*-(coumarin-3-carbonyl)hydrazinocarbonyl]-thiphen-2-yl}hydrazide (27).* A solution of **24** (0.5 g, 1.85 mmol) in 20 mL of absolute ethanol containing few drops of piperidine was treated with sulfur flower (0.128 g, 2 mmol) in 10 mL absolute ethanol, the mixture was stirred well under nitrogen at 70-90 °C for 30 minutes, the solid obtained was collected by filtration and washed several times with hot ethanol, then finally with acetone to give a pale yellow crystals of **27** (0.86 g, 84 %), m.p. > 360 °C, insoluble in most organic solvents, $C_{26}H_{16}O_7N_6S$ (556); IR (KBr disc): 3299, 3220 (NH), 3080, 3044 (Ar-H), 2259 (CN), 1706 (CO); Ms (%): m/z 556 ([$M^+$], 1), 544 (1), 377 (3), 376 (13), 173 (100), 145 (3), 101 (20), 89 (17), 44 (4).

**Crossover experiment**. The procedure as above, a mixture of **24** (0.5 g, 1.85 mmol) in 20 mL of absolute ethanol was treated with a mixture of sulfur flower (0.128 g, 2 mmol) and malononitrile (1.22 g, 1.85 mmol) and a few drops of piperidine in 10 mL ethanol, and completed as above. The obtained solid was identical with authentic sample of **27** (m.p. and mixed m.p.) as the unique compound.

**Interaction of coumarin-3-carbonyl chloride (1) with dibasic aliphatic amines: Bis-(coumarin-3*N*-yl)alkylcarboxamides (30, 31).** To a well stirred solution of **1** (0.417 g, 2 mmol) in DCM 20 mL containing few drops of TEA, was added an equivalent amount of dibasic aliphatic amine (2.1 mmol). The reaction mixture was stirred at room temperature under dry conditions for 2 hours. The DCM was removed under reduced pressure till dryness, the obtained solid was washed with 10 % HCl and the remaining was crystallized from proper solvent.

***N*,*N*'-Bis-(2-oxo-2*H*-chromene-3-carbonyl)propane-1,3-diamine (30a).** White needles (0.25g, 60%) m.p. 258°C; IR (KBr disc): 3359 (NH), 3058 (Ar-H), 2971, 2922, 2867 (CH-aliph.), 1702 (CO).; PMR (DMSO-$d_6$): δ 1.80 (2H, m, $CH_2$, 3.40 (4H, m, $(CH_2NH)_2$), 7.37-7.96 (8H, m, Ar-H), 8.82 (2H, s, 2H-4), 8.70 (2H, hump, 2NHCO).; Ms (%): *m/z* 418 ([$M^+$], 0), 230 (6), 229 (44), 173 (100), 146 (11), 118 (4), 101 (20), 89 (19), 63 (6), 44 (17); $C_{23}H_{18}N_2O_6$ (418.41);Cal.: C, 66.02; H, 4.34; N, 6.69; Found: C, 66.20; H, 4.42; N, 6.75.

***N*,*N*'-Bis-(2-oxo-2*H*-chromene-3-carbonyl)butane-1,4-diamine (30b).** Colorless needles (0.26, 60.19%) m.p. 240-1°C; IR (KBr disc): 3312 (NH), 2971, 2834, 2855 (CH), 1706 (CO).; PMR (DMSO-$d_6$): δ 1.60, 3.37 (8H, 2set of multipletes, $(CH_2)_4$), 7.45, 7.73, 7.94 (8H, 3set of multipletes, Ar-H), 8.65 (2H, hump, 2CONH), 8.70 (2H, s, 2H-4).; Ms (%): *m/z* 432 ([$M^+$], 1), 243 (35), 202 (5), 173 (100), 146 (9), 118 (5), 101 (23), 89 (22), 44 (40); $C_{24}H_{20}N_2O_6$ (432.44) Cal.: C, 66.66; H, 4.66; N, 6.48; Found: C, 66.78; H, 4.61; N, 6.59.

***N*,*N*'-Bis-(2-oxo-2*H*-chromene-3-carbonyl)hexane-1,6-diamine (30c).** White needles (0.30 g, 67.39%) m.p. 218°C; IR (KBr disc): 3321, (NH), 3056, (Ar-H), 2971, 2928, 2849 (CH-aliph.), 1704 (br), 1657 (CO).; PMR (DMSO-$d_6$): δ 1.38, 1.56 (8H, m, $(CH_2)_4$), 3.32 (4H, m, $(CH_2N)_2$), 7.34-7.95 (8H, m, Ar-H), 8.61 (2H, hump, $(CONH)_2$), 8.79 (2H, s, 2H-4).; Ms (%): *m/z* 460 ([$M^+$], 3), 314 (5), 287 (13), 270 (24), 258 (13), 216 (4), 173 (100), 146 (8), 101 (23), 98 (23), 89 (21), 44 (6); $C_{26}H_{24}N_2O_6$ (460.49); Cal.: C, 67.82; H, 5.25; N,6.08; Found: C, 67.88; H, 5.33; N, 6.19.

***N*,*N*'-Bis-(2-oxo-2*H*-chromene-3-carbonyl)-1,3-phenylene-dimethaneamine (31).** Colorless crystals (0.37, 76.30%) m.p. 238°C; IR (KBr disc): 3348, 3323, (NH), 3050 (Ar-H), 2971, 2934, 2873 (CH-aliph.), 1712, 1700 (CO).; PMR (DMSO-$d_6$): δ 4.53 (2H, s, $CH_2$), 4.56 (2H, s, $CH_2$), 7.26-7.45 (8H, m, Ar-H), 7.68-7.77 (2H, m, Ar-H), 7.91, 7.95 (2H, 2s, Ar-H), 8.83 (2H, s, H-4), 9.06 (2H, hump, $(CONH)_2$).; Ms (%): *m/z* 480 ([$M^+$], 5), 173 (100); $C_{28}H_{20}N_2O_6$ (480.48); Cal.: C, 69.99; H, 4.19; N, 5.88; Found: C, 70.12; H, 4.14; N, 5.87.

**Coumarin-3-carboxylic acid anhydride (33).** To a well stirred solution of coumarin-3-carbonyl chloride (**1**) (2.08 g, 10 mmol) in 20 mL DCM was added coumarin-3-carboxylic acid (**32**) (1.90 g, 10 mmol) solution in 20 mL DCM containing 1 g anhydrous $K_2CO_3$ under nitrogen atmosphere. The stirring was continued for 6 hours at 90-100 °C. The reaction mixture was cooled and the solid precipitate was filtered. The DCM was remove under reduced pressure and the straw yellow crystals were collected by filtration (1.22 g, 33 %) m.p. 248-50 °C, $C_{20}H_{10}O_6$; IR (KBr disc): 3062 (Ar-H), 1795, 1730, 1709 (CO). PMR (DMSO-$d_6$): δ 7.27-8.00 (8H, m, Ar-H), 8.75 (2H, s, 2H-4).; Ms (%): *m/z* 362 ([$M^+$], 10), 318 (1), 290 (19), 262 (7), 234 (2), 173 (100), 146 (10), 145 (9), 118 (7), 89 (36), 63 (24), 51 (7); $C_{20}H_{10}O_7$ (362.29); Cal.: C, 66.31; H, 2.78; Found: C, 66.39; H, 2.71.

**Synthesis of 1-Chloromethyl-8/9-substitutedbenzo[*f*]coumarin derivatives (36a-d).**

**Method (A).** An appropriate 2-naphthol or its derivatives (**34a-d**) (3.2 g; 20 mmol) and ethyl 4-chloroacetoacetate (**35**) (3.62 g, 22 mmol) were combined in a 50 mL round bottom flask, 10 mL of concentrated $H_2SO_4$ was then added and the reaction mixture was stirred for 24 hours at room temperature. The reaction mixture was poured into ice water and stirred for 2 hours to give a fine precipitate. The filtrate was collected by filtration, washed with cooled water and ether, and then dried (yield 63-71 %).

**Method (B).** An appropriate 2-naphthol or its derivatives (**34a-d**) (2.015 g; 12.5 mmol) and ethyl 4-chloroacetoacetate (**35**) (2.34 g, 14.2 mmol) were combined in a 50 mL round bottom flask, this mixture was then kept in an ice-bath at 0 °C, 5 mL of concentrated $H_2SO_4$ was then added over a period of 30 minutes. Afterwards, the mixture stirred at room temperature for 3 hours. The reaction mixture was poured into ice water and stirred for 2 hours to give a fine precipitate. The precipitate was collected by filtration, washed with cooled water and ether, and then dried (yield 87-93 %).

**Method (C).** An appropriate 2-naphthol or its derivatives (**34a-d**) (3.2 g; 20 mmol) and ethyl 4-chloroacetoacetate (**35**) (3.62 g, 22 mmol) were combined in a 50 mL round bottom flask, anhydrous $ZnCl_2$ was then added and the reaction mixture was heated at 120-5 °C for 2 hours. The residual solid was treated with ethanol (95 %), collected by filtration, washed and dried (yield 33-40 %).

**Method (D).** The procedure in method C except that anhydrous ethanol was used as a solvent (yield 15-23 %).

**Synthesis of 4-chloromethyl-7/8-substitutedbenzo[*h*]-coumarin derivatives (38a,b and 40).** A mixture of 1,5-, 1,6-dihydroxynaphthalene or 4-chloro-1-naphthol (**37a,b or 39**) (20 mmol) and ethyl 4-chloroacetoacetate (**35**) (3.62 g, 22 mmol) were combined in a 50 mL round bottom flask, the work-up procedure is similar to method B.

**Synthesis of 4-(chloromethyl)pyrano[3,2-*c*]chromene-2,5-dione (42).** A mixture of 4-hydroxycoumarin (**41**) (3.24 g, 20 mmol), ethyl 4-chloroacetoacetate (**35**) (3.62 g, 22 mmol),

anhydrous aluminum chloride was combined in 50 mL round bottom flask, 20 mL of dry nitrobenzene was then added. The reaction mixture was refluxed at 130-40 °C for 4 hours. The nitrobenzene was evaporated by steam bath, the residual solid was then treated with ethanol, filtered, washed and dried (yield 1.85 g, 70 %).

**1-(Chloromethyl)-3*H*-benzo[*f*]chromen-3-one (36a).** Creamy (4.5g, 93%) m.p. 160°C; IR (KBr disc): 1734.42 (C=O); PMR (DMSO-$d_6$): δ 5.41 (s, 2H, -$CH_2$), 6.87 (s, 1H, H-2), 7.58-7.75 (m, 3H, Ar-H), 8.07, 8.11 (d, 1H, Ar-H), 8.23, 8.27 (d, 1H, Ar-H), 8.52, 8.57 (d, 1H, Ar-H); $C_{14}H_9O_2Cl$ (244.68); Cal.: C, 68.72; H, 3.71; Found: C, 68.64; H, 3.65.

**1-(Chloromethyl)-8-hydroxy-3*H*-benzo[*f*]chromen-3-one (36b).** Green (5.10g, 98%) m.p. 240°C; IR (KBr disc): 3286.55 (OH), 1688.2 (C=O); PMR (DMSO-$d_6$): δ 5.29 (s, 2H, -$CH_2$), 6.76 (s, 1H, H-2), 7.13, 7.18 (d, 1H, H-5), 7.89, 7.94 (d, 1H, H-6), 8.06, 8.11 (d, 1H, H-7), 10.19 (s, 1H, OH; cancelled by $D_2O$); $^{13}C$ NMR (APT) (DMSO-$d_6$) δ = 46.09 ($CH_2$), 108.58 (C-10), 110.59 (C-10b), 113.81 (C-2), 115.66 (C-5), 117.17 (C-8), 125.15 (C-6a), 130.23 (C-10a), 131.25 (C-6), 134.22 (C-7), 152.11 (C-4a), 155.25 (C-9), 157.74 (C-1), 159.30 (C=O); $C_{14}H_9O_3Cl$ (260.68); Cal.: C, 64.51; H, 3.48; Found: C, 64.54; H, 3.50.

**1-(Chloromethyl)-9-hydroxy-3*H*-benzo[*f*]chromen-3-one (36c).** Yellow (3.54g, 68%) m.p. 220°C; IR (KBr disc): 1737 (C=O); PMR (DMSO-$d_6$): δ 5.34 (s, 2H, -$CH_2$), 6.81 (s, 1H, H-2), 7.27, 7.28 (d, 1H, H-5), 7.30 (s, 1H, H-7), 7.45, 7.48 (d, 1H, H-6), 8.01, 8.04 (d, 1H, H-9), 8.36, 8.39 (d, 1H, H-10), 10.09 (brs, 1H, OH; cancelled by $D_2O$); CMR (DMSO-$d_6$) δ = 46.34 ($CH_2$), 111.29 (Ar-CH), 112.06 (Ar-C), 116.77 (2-CH), 117.58 (Ar-CH), 119.96 (Ar-CH), 121.88 (Ar-C), 127.08 (Ar-CH), 132.92 (Ar-C), 132.97 (Ar-CH), 151.70 (Ar-C), 152.88 (Ar-C), 154.99 (1-C), 159.39 (CO); $C_{14}H_9O_3Cl$ (260.68); Cal.: C, 64.51; H, 3.48; Found: C, 64.70; H, 3.57.

**9-Bromo-1-(chloromethyl)-3*H*-benzo[*f*]chromen-3-one (36d).** Off-white (5.36g, 83%) m.p. 210°C; IR (KBr disc): 1736 (C=O); PMR (DMSO-$d_6$) δ 5.34 (s, 2H, -$CH_2$), 6.85 (s, 1H, H-2), 7.60, 7.63 (d, 1H, H-5), 7.81, 7.84 (d, 1H, H-6), 8.18, 8.21 (d, 1H, H-9), 8.36 (s, 1H, H-7), 8.52, 8.55 (d, 1H, H-10). CMR (DMSO-$d_6$) δ = 46.14 ($CH_2$), 112.11 (2-CH), 117.51 (Ar-C), 118.89 (Ar-CH), 127.04 (Ar-CH), 127.95 (Ar-CH), 128.86 (Ar-C), 129.34 (Ar-CH), 130.89 (Ar-CH), 131.18 (Ar-CH), 132.43 (Ar-C), 151.48 (Ar-C), 154.80 (2-CH), 159.02 (CO); $C_{14}H_8O_2BrCl$ (323.57); Cal.: C, 51.97; H, 2.49; Found: C, 52.04; H, 2.58

**4-(Chloromethyl)-7-hydroxy-2*H*-benzo[*h*]chromen-2-one (38a).** Deep green (4.06g, 78%) m.p. 205°C; IR (KBr disc): 1728 (C=O), 3412 (OH); PMR (DMSO-$d_6$) δ 5.12 (s, 2H, -$CH_2$), 6.72 (s, 1H, H-3), 7.06, 7.09 (d, 1H, H-8), 7.45 (t, 1H, H-9), 7.70, 7.73 (d, 1H, H-5), 7.74,7.77 (d, 1H, H-6), 8.01, 8.04 (d, 1H, H-10), 5.95 (brs, 1H, OH; cancelled by $D_2O$); CMR (DMSO-$d_6$) δ = 41.76 ($CH_2$), 108.36 (Ar-CH), 112.72 (3-CH), 114.84 (Ar-CH), 118.45 (Ar-CH), 123.75 (Ar-C), 124.90 (Ar-CH), 125.62 (Ar-C), 126.06 (Ar-C), 128.30 (Ar-CH), 151.51 (Ar-C), 153.07 (Ar-C), 153.54 (4-CH), 159.74 (CO); $C_{14}H_9O_3Cl$ (260.68); Cal.: C, 64.51; H, 3.48; Found: C, 64.59; H, 3.58.

**4-(Chloromethyl)-8-hydroxy-2*H*-benzo[*h*]chromen-2-one (38b).** Yellow (3.80g, 73.00%) m.p. 170°C; IR (KBr disc): 1711 (C=O), 3382 (OH); PMR (DMSO-$d_6$) δ 5.06 (s, 2H, -$CH_2$), 6.65 (s, 1H, H-3), 7.23 (s, 1H, H-7), 7.26, 7.27 (d, 1H, H-9), 7.66, 7.70 (d, 1H, H-6), 7.73, 7.74 (d, 1H, H-5), 8.28, 8.31 (d, 1H, H-10), 10.05 (brs, 1H, OH; cancelled by $D_2O$); CMR (DMSO-$d_6$) δ = 41.74 ($CH_2$), 109.55 (Ar-CH), 112.92, (3-CH), 116.29 (Ar-C), 119.68 (Ar-CH), 121.00 (Ar-CH), 122.67 (Ar-CH), 123.75 (Ar-CH), 131.26 (Ar-C), 136.77 (Ar-C), 150.97 (Ar-C), 151.77 (Ar-C), 158.26 (4-CH), 159.80 (CO); $C_{14}H_9O_3Cl$ (260.68); Cal.: C, 64.51; H, 3.48; Found: C, 64.78; H, 3.47.

**6-Chloro-4-(chloromethyl)-2*H*-benzo[*h*]chromen-2-one (40).** Off-white (2.68g, 48.00%) m.p. 185°C; IR (KBr disc): 1735 (C=O); PMR (DMSO-$d_6$) δ 5.06 (s, 2H, -$CH_2$), 6.75 (s, 1H, H-3), 7.69-7.81 (m, 2H, H-8, 9), 7.90 (s, 1H, H-5), 8.07, 8.10 (d, 1H, H-10), 8.24, 8.27 (d, 1H, H-7); CMR (DMSO-$d_6$) δ = 45.98 ($CH_2$), 115.63, 121.04, 122.45, 123.79, 124.21, 125.124, 125.27, 126.34, 128.55, 130.39, 130.81, 150.68, 152.76 (Ar-C, Ar-CH), 159.07 (CO); $C_{14}H_8O_2Cl_2$ (279.12); Cal.: C, 60.24; H, 2.89; Found: C, 60.22; H, 2.80.

**3-(Chloromethyl)-2*H*-benzo[*h*]chromen-2-one (42).** Yellowish-white (3.62g, 69.00%) m.p. >300°C; IR (KBr disc): 1729, 1765 (C=O); PMR (DMSO-$d_6$) δ 4.24 (s, 2H, -$CH_2$), 6.02 (s, 1H, H-3), 7.34-7.53 (m, 2H, H-8,9), 7.61-8.01 (m, 2H, H-7,10); CMR (DMSO-$d_6$) δ 29.30 ($CH_2$), 112.82 (C-4a), 116.19 (C-3), 116.59 (C-10a), 123.44 (C-7), 123.77 (C-9), 125.15 (C-10), 132.15 (C-8), 152.58 (C-6a), 156.53 (C-10b), 157.80 (C-1), 162.40 (C-5), 162.72 (C-2); $C_{13}H_7O_4Cl$ (262.65); Cal.: C, 59.45; H, 2.69; Found: C, 59.67; H, 2.76.

**Synthesis of 2-(Naphtho[2,1-*b*]furan-1-yl)acetic acid (43).** A mixture of **36a** (1.22 g, 5 mmol) and KCN (0.326 g, 5 mmol) was refluxed in 20 mL of EtOH/$H_2O$ mixture (1:1) for four hours. The ethanol was then evaporated and the clear yellow aqueous solution was acidified by 2 mL of concentrated HCl to give a white precipitate. The precipitate was collected by filtration, washed with water and dried under reduced pressure.

**2-(Naphtho[2,1-*b*]furan-1-yl)acetic acid (43).** Grey (0.90g, 79.00%) m.p.145°C; IR (KBr disc): 1707 (CO), 3421 (br. OH).; PMR (DMSO-$d_6$) δ 4.06 (2H, s, $CH_2$), 7.50, 7.53 (1H, d, Ar-H), 7.58, 7.60 (1H, d, Ar-H), 7.75-7.85 (2H, m, Ar-H), 8.02, 8.05 (2H, d, Ar-H + H-furan), 8.18, 8.21 (1H, d, Ar-H), 12.62 (1H, hump, COOH, cancelled by $D_2O$).; CMR (DMSO-$d_6$) δ 31.38 ($CH_2$), 116.16 (furan-C), 113.32, 121.54, 123.44, 125.08, 126.34, 127.14, 128.39, 129.63, 130.89 (Ar-C and Ar-CH), 144.19 (furan-CH), 153.26 (Ar-C), 173.00 (CO).; Ms (%): *m/z* 226 ([$M^+$], 100), 45 ([$M^+$ - H, $CO_2$], 81), 152 ([$M^+$ - H, $CO_2$, CHO], 60), 126 ([$M^+$ - H, $CO_2$, CHO, $C_2H_2$], 6), 76 ([$M^+$ - H, $CO_2$, CHO, $C_2H_2$, $C_4H_2$], 9); $C_{14}H_{10}O_3$ (226.23); Cal.: C, 74.33; H,, 4.45; Found: C, 74.53; H, 4.57.

**Synthesis of 2-(benzo[*f*]coumarin-1-yl)acetic acid, 2-(benzo[*f*]coumarin-1-yl)acetonitrile and 2-naphthol (44 and 45).** To a stirred solution of **36a** (1.22 g, 5 mmol) in DMSO (10 mL), KCN (0.326 g, 5 mmol) was added and the stirring was continued for 1 hour under nitrogen at room temperature. The reaction mixture was poured into 100 mL of water. The solid formed was collected by filtration, washed with water and dried, it has characterized as **45** (yield, 0.25 g, 70.95%). The yellowish filtrate was treated with 3 mL of concentrated hydrochloric acid to produce **44** and **34a**. The solid was collected by filtration and washed with cooled water and ether to give **44** (yield, 0.07 g, 19.86 %), the ether layer was evaporated and the solid formed was characterized as 2-naphthol (**34a**) (yield, 0.03 g, 8.51 %).

Crossover experiments for (44). Compound **44** was prepared independently according to procedure in literature [45].

**2-(3-Oxo-3*H*-benzo[*f*]chromen-1-yl)acetic acid (44).** Off-white (0.07g, 19.86%) m.p. 200°C;IR (KBr disc): 1664, 1719 (2CO), 3425 (br. OH).; PMR (DMSO-$d_6$) δ 4.35 (2H, s, $CH_2$), 6.61 (1H, s, H-2), 7.54-7.70 (3H, m , Ar-H), 8.04, 8.07 (1H, d, Ar-H), 8.17, 8.20 (1H, d, Ar-H), 8.36, 8.39 (1H, d, Ar-H).; CMR (DMSO-$d_6$) δ 42.91 ($CH_2$), 113.68 (C-2), 117.75, 118.35,

124.34, 125.65, 128.36, 129.29, 129.92, 131.02, 134.15, 151.09 (Ar-C and Ar-CH), 154.44 (C-1), 159.45 (CO-lactone), 171.08 (COOH); $C_{15}H_{10}O_4$ (254.24); Cal.: C, 70.86; H, 3.96; Found: C, 70.84; H, 3.95.

**1-(Chloromethyl)-3*H*-benzo[*f*]chromen-3-one (45).** Brownish (0.25g, 70.95%) m.p. 243°C; IR (KBr disc): 1770 (C=O), 2242 (CN).; Ms (%): *m/z* 235 ([$M^+$], 81), 207 (100), 181 (26), 152 (46), 126 (8), 76 (36); $C_{15}H_9NO_2$ (235.24); Cal.: C, 76.59; H, 3.86;N, 5.95; Found: C, 76.78; H, 3.79.

**Synthesis of 2-(8-bromobenzo[*f*]coumarin-1-yl)acetonitrile, 1-((6-bromonaphthalen-2-yloxy)methyl)-benzo[*f*]coumarin and 6-bromo-2-naphthol (47 and 48).** To a stirred solution of **36d** (1.62 g, 5 mmol) in DMSO (10 mL), KCN (0.326 g, 5 mmol) was added and the stirring was continued for 30 minutes under nitrogen at room temperature. The reaction mixture was poured into 100 mL of water. The solid formed was collected by filtration, washed with water and dried, to give **48** (yield, 0.28 g, 86.67%). The coloured filtrate was treated with 3 mL of concentrated hydrochloric acid to produce **47** and **34d**. The solid was collected by filtration and washed with cooled water, ether and dried to give **47** (yield, 0.03 g, 9.29 %), the ethereal solution was evaporated and the solid formed was characterized as 6-bromo-2-naphthol (**34d**) (yield, 0.01 g, 3.09 %).

**Crossover experiment for (48).** To a stirred solution of **36d** (1.62 g, 5 mmol) in DMSO (5 mL), a solution of 6-bromo-2-naphthol (**34d**) (1.12 g, 5 mmol) in DMSO (5 mL) was added; $K_2CO_3$ (1.11 g, 8 mmol) was used as a catalyst. The reaction mixture was stirred for 1 hour under nitrogen and then poured into 100 mL water. The solid formed (**48**) was collected by filtration, washed with cooled water and dried.

**2-(8-Bromo-3-oxo-3*H*-benzo[*f*]chromen-1-yl)acetonitrile (47).** IR (KBr disc): 1724 (CO), 2186 (CN).; Ms (%): *m/z* 314 ([$M^+$], 15), 316 ([$M^+$ +2], 13), 286 (39), 260 (11), 231 (2), 206 (100), 75 (40).

**8-Bromo-1-((naphthalen-2-yloxy)methyl)-3*H*-benzo[*f*]-chromen-3-one (48).** IR (KBr disc): 1730 (CO).; PMR (DMSO-$d_6$) δ 5.86 (2H, s, $CH_2$), 6.88 (1H, s, H-2), 7.42-8.30 (11H, m, Ar-H).

**Synthesis of 2-(9-hydroxybenzo[*f*]coumarin-1-yl)acetonitrile (49).** To a stirred solution of **36b** (1.30 g, 5 mmol) in DMSO (10 mL), KCN (0.326 g, 5 mmol) was added and the stirring was continued for 1 hour under nitrogen at room temperature. The reaction mixture was poured into 100 mL of water. The solution was acidified with few drops of concentrated hydrochloric acid then the solid was collected by filtration, washed with cooled water and dried to give **49** (yield, 1 g, 79.68 %).

**2-(9-Hydroxy-3-oxo-3*H*-benzo[*f*]chromen-1-yl)acetonitrile (49).** White crystals (1.00g, 79.68%) m.p.239°C; IR (KBr disc): 1700 (C=O), 2243 (CN), 3345 (OH).; PMR (DMSO-$d_6$) δ 4.78 (2H, s, $CH_2$), 6.59 (1H, s, H-2), 7.15, 7.18 (1H, d, Ar-H), 7.30, 7.33 (1H, d, Ar-H), 7.68 (1H, s, Ar-H), 7.91, 7.94 (1H, d, Ar-H), 8.08, 8.11 (1H, d, Ar-H), 10.19 (1H. s, OH, cancelled by $D_2O$).; CMR (DMSO-$d_6$) δ 25.84 ($CH_2$), 108.39, 110.88, 113.83, 114.68, (Ar-CH), 116.04 (Ar-C), 117.26 (CN), 125.22 (Ar-C), 130.45 (Ar-CH), 131.58, 134.66 (Ar-CH), 147.75 (Ar-C), 155.07 (2-CH), 157.74 (Ar-C), 158.82 (CO); $C_{15}H_8O_2NBr$ (314.13); Cal.: C, 57.35; H, 2.57; N, 4.46; Found: C, 57.43; H, 2.55; N, 4.50.

**Synthesis of 1-((benzo[*d*]thiazol-2-yl)methyl)-9-hydroxy-benzo[*f*]coumarin (50).** To a stirred solution of **49** (0.251 g, 1 mmol) in EtOH (10 mL), a solution of 2-aminothiophenol (**5**) (0.125 g, 1 mmol) in EtOH/TEA (10 mL) was added and then the mixture was refluxed for 2 hour under nitrogen. Afterwards, the solvent was evaporated under reduced pressure to produce a brown solid, which was then washed with dichloromethane several times until the dichloromethane solution gets colourless. The solid was then collected by filtration, washed with ether and dried.

**1-(Benzo[*d*]thiazol-2-ylmethyl)-9-hydroxy-3*H*-benzo[*f*]-chromen-3-one (50).** Brown crystals (0.28g, 86.67%) m.p. > 300°C; IR (KBr disc): 1705 (C=O), 3420 (OH).; Ms (%): m/z 359 ([$M^+$], 13), 331 (15), 302 (10), 142 (5), 74 (17); $C_{24}H_{14}O_3Br_2$ (510.18); Cal.: C, 56.50; H, 2.77; Found: C, 56.52; H, 2.78.

**Experimental procedure for photophysical studies.** Herein, luminescence spectra (excitation and emission) for the prepared benzocoumarin derivatives have been recorded on a double monocromator Fluorolog 1902 insturment from Spex. The source was a 400 W Hg-Xe high pressure lamp using 1 cm [46-50] quartz cell in 2-methyltetrahydrofuran solvent at room temperature. Fluorescence quantum yield for the studied compounds determined in reference to 9,10-diphenylanthracene [47]. Solutions of the recorded samples were prepared under an Ar atmosphere to avoid any possible quenching by atmospheric $O_2$. Both of the standard and sample solutions were in the 0.05 absorption range at the wavelength of excitation.

**Antibacterial Bioassay**. Sterile 6mm diameter paper discs were loaded with 250 microgram of each compound and dried over night under reduced air pressure, at room temperature to evaporate the solvent. Dried blank discs with solvent were also used as negative control in order to monitor the experiment. These discs were placed on pre-cultured agar plates and incubated at 37 °C overnight. The diameter of zone of inhibition of each disc was recorded in mm. The bioassay was run in a triplicate.

**Acknowledgements.** Financial support for this work provided by the Natural Sciences and Engineering Research Council of Canada (NSERC) and The University of Winnipeg is gratefully acknowledged.

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