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REVIEW

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3-(Bromoacetyl)coumarins: unraveling their synthesis, chemistry, and applications

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This review emphasizes recent developments in synthetic routes of 3-(bromoacetyl)coumarin derivatives. Also, chemical reactions of 3-(bromoacetyl)coumarins as versatile building blocks in the preparation of critical polyfunctionalized heterocyclic systems and other industrially significant scaffolds are described. Recent advances of 3-(bromoacetyl)coumarins as attractive starting points towards a wide scale of five and six-membered heterocyclic systems such as thiophenes, imidazoles, pyrazoles, thiazoles, triazoles, pyrans, pyridines, thiadiazins as well as fused heterocyclic systems have been reported. Additionally, this review covers a wide range of analytical chemistry, fluorescent sensors, and biological applications of these moieties, covering the literature till May 2021.

1. Introduction

Coumarins are one of the most common host heterocyclic systems reported in the literature of organic chemistry.[1,2] Furthermore, coumarins and their derivatives are seen to be the pivotal components of a plethora of many natural products and pharmaceuticals[3] and synthetic dyes.[4–9] The pharmacological activities discovered amongst coumarin derivatives include the treatment categories of Alzheimer's[10] and haematopoietic necrosis (IHN);[11] they have shown potent anticoagulant, antibiotic, antiembolic, antioxidative, and anti-ischemic activities[12–16] (Fig. 1).

Among these compounds, 3-(bromoacetyl)coumarin **1** and its derivatives are a prominent structural class in the synthesis of various bioactive heterocyclic scaffolds,[17,18] they also are important components in drug discovery on account of their biological activities such as antiproliferative, antimicrobial activities,[19] and are promising inhibitors of type 2 diabetes mellitus.[20] In addition, numerous chemosensors are based on polyfunctional coumarin platforms used to detect multianalyte detection, such as different bioactive elements and various environmental pollutants.[21,22] There is no survey available on the biological and chemical applications achieved since the discovery of 3-(bromoacetyl)coumarins. The articles on this type of coumarin are scattered in scientific journals.

In continuation of our investigations on the chemistry of coumarins and their azo/thio isosteric analogs[23–28] and based on the above mentioned interesting biological and chemical aspects, this survey mainly highlights the advances in the synthesis of 3-(bromoacetyl)coumarin and its derivatives, besides, their transformations for the construction of different fused heterocyclic systems in detail. Additionally, a wide range of analytical chemistry, fluorescent sensors, and biological applications of these moieties are summarized.

2. Spectral data

Many papers have reported the spectroscopic measurements (IR, ^{1}H NMR, ^{13}C NMR, and Mass) of 3-(bromoacetyl) coumarin.[29,30] As IR spectrum of 3-(bromoacetyl)coumarin showed the characteristic ketonic group band at 1674, while C–H stretching vibrations at the aromatic region 3100–3000 cm^{-1} (ref. 29) and two carbonyl characteristic peaks at ν 1674 and 1729 cm^{-1} related to α,β-unsaturated ketonic and lactonic, respectively.[31] ^{1}H NMR spectrum of parent 3-(bromoacetyl)coumarin **1** shows singlet signal of H-4 at δ = 8.63 ppm, while the CH_2 group appears as singlet signal at δ = 4.74 ppm. Also, ^{13}C NMR spectrum of 3-(bromoacetyl)coumarin exhibits characteristic signals at δ = 188.9, 158.9, and 35.6 ppm corresponding to α,β-unsaturated ketonic, lactonic and methylene carbons, respectively.[30] In the same context, HRMS/MS is mentioned as characteristic spectrometric data for 3-(bromoacetyl)coumarin **1** shows that *m*/*z* 266.9665 (calcd. for $C_{11}H_8{}^{79}BrO_3$ $[M + H]^+$ 266.9657).[30]

In 1991, Vasudevan *et al.*[32] elucidated the structure 3-(bromoacetyl)coumarin **1** through its single-crystal X-ray, which showed that there are two conformers of the structure **1**, *S-cis* (I) or *S-trans* (II) (Fig. 2).

Moreover, Sparkes and coworkers[33] reported a polymorph of 3-(bromoacetyl)coumarin (Fig. 3). Whereas, Chennuru *et al.*[34]

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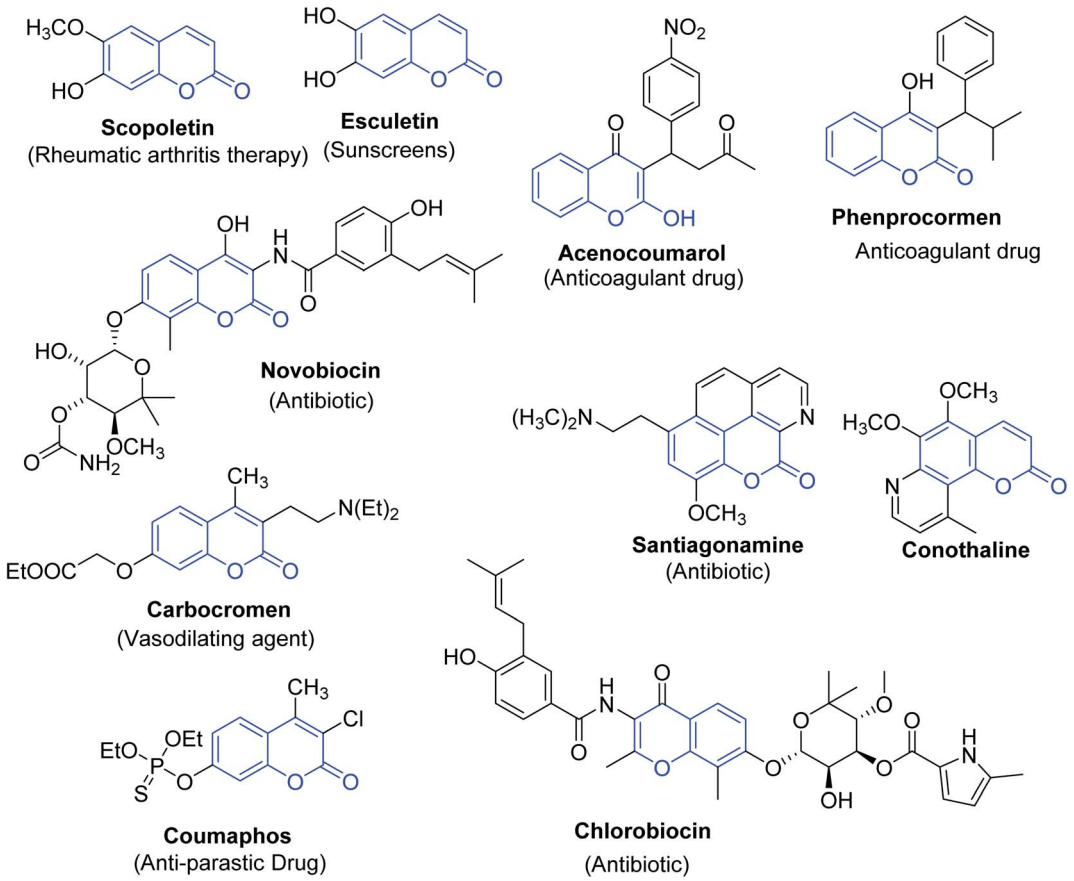


Fig. 1 Selected structures of coumarin derivatives in biological applications.

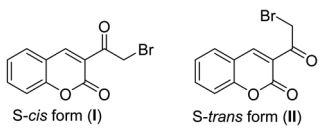


Fig. 2 *S-cis* (I) or *S-trans* (II) conformers of 3-(bromoacetyl)coumarin **1**.

reported a single-crystal X-ray of 6-chloro-3-(bromoacetyl) coumarin (Fig. 4).

3. Synthesis

3.1. Using 3-acetylcoumarins

The reaction of 3-acetylcoumarins **2** with numerous reagents represents a general approach to preparing 3-bromoacetyl coumarin derivatives **1**. Several brominating agents have been reported in the last two decades such as tetrabutylammonium tribromide (TBATB), bromine, phenyltrimethylammonium tribromide ($PhTAPBr_3$), *N*-bromosuccinimide (NBS), and copper(II) bromide ($CuBr_2$) (Scheme 1).[35–47]

4. Reactivity

On the treatment of 3-(bromoacetyl)coumarin **1** with various nucleophiles, four possible electrophilic positions are susceptible to attack: the exo-carbonyl group (position 1), bromomethanide group (CH_2Br) (position 2), lactonic carbonyl group

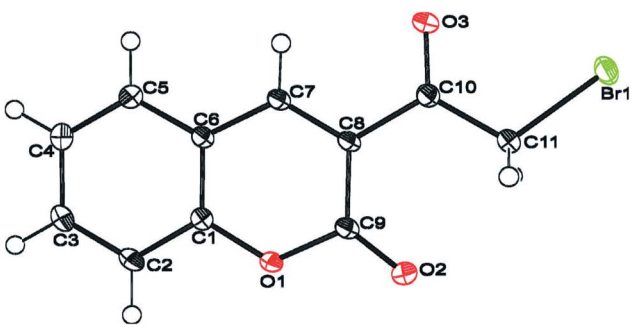


Fig. 3 ORTEP diagram of 3-(bromoacetyl)coumarin **1** [reprinted from ref. 33].

(position 3) and the bromo atom (position 4) susceptible to attack (Fig. 5). Besides, the typically nucleophilic position for attacking is carbon 4. The reactivity of α-bromoacetylcoumarin towards oxygen, nitrogen, and sulphur nucleophiles is discussed in this review.

5. Reactions

5.1. Amination

Sinnur *et al.*[48] reported a short and efficient synthesis for aminomethyl-3-coumarinyl ketone hydrochloride **4** *via*

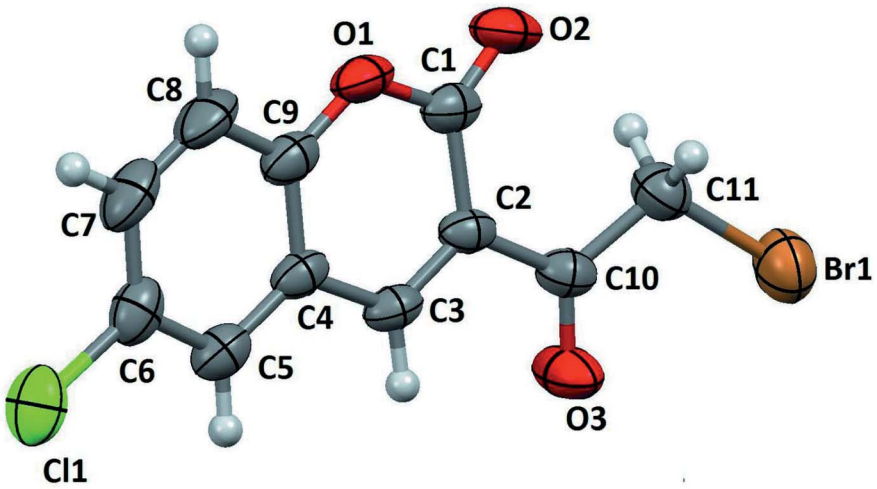


Fig. 4 ORTEP diagram of 6-chloro-3-(bromoacetyl)coumarin [reprinted from ref. 34].

Condition A: TBATB, AcOH, RT / 2h [35,36]
Condition B: Br_2 in $CHCl_3$ or AcOH, reflux [37-40]
Condition C: $PhTAPBr_3$, THF, 25 °C, 15 min [41-42]
Condition D: NBS, *p*-TSA, 4h, reflux [43]
Condition E: $CuBr_2$, EtOH, 80 °C [44]
Condition F: $CuBr_2$, EtOH, 300W, 100 °C, 2 min [45]
Condition G: $CuBr_2$ in $CHCl_3$/EtOAc [46, 47]

1a, 2a: R_1=R_2=R_3 =R_4=H
1b, 2b: R_1= NEt_2, R_2=R_3=R_4= H
1c, 2c: R_1=H, R_2=R_3=R_4 CH=CH-CH=CH
1d, 2d: R_1= OH, R_2=R_3=R_4= H
1e, 2e: R_1= OH, R_2=R_3=R_4= H
1f, 2f: R_1= OMe, R_2=R_3=R_4= H
1g, 2g: R_1=R_2=R_3= H, R_4 = Cl;
1h, 2h: R_1 = OMe, R_2 = $CH_2CH=CH_2$, R_3=R_4= H
1i, 2i: R_1=R_2=R_3= H, R_4 = OCH_3
1j, 2j: R_1 = OMe, R_2 = Cl, R_3=R_4= H

Scheme 1 Formation of 3-(bromoacetyl)coumarin derivatives **1**.

refluxing 3-(bromoacetyl)coumarin **1** with hexamethylenetetramine **3** in drops of concentrated hydrochloric acid (Scheme 2).

Moreover, 3-(bromoacetyl)coumarin 1 was condensed with an amino group of various heterocyclic derivatives 5 such as 2-aminothiazole, 2-aminobenzothiazole, 2-amino-1,3,4-oxadiazole, 2-amino-1,3,4-thiadiazole, and 3-amino-4*H*-1,2,4-triazole derivatives in DMF to give the corresponding 2*H*-chromen-2-ones 6 (Scheme 3).[49]

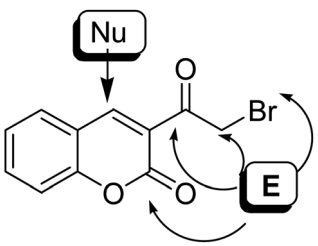
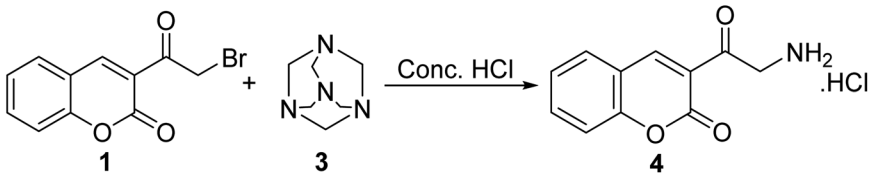


Fig. 5 Reactive sites in 3-(bromoacetyl)coumarin.

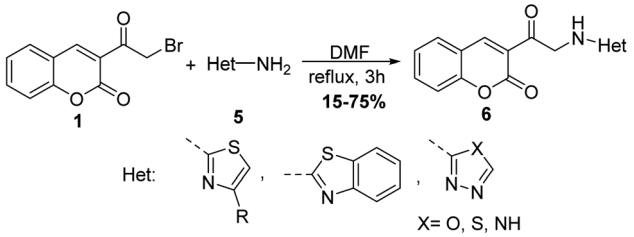
Treatment of 3-(bromoacetyl)coumarin **1** with di(2-picolyl) amine 7 in chloroform under basic condition at room temperature afforded the corresponding 3-(bis(pyridin-2-ylmethyl) glycyl)-2*H*-chromen-2-one **8** (Scheme 4).[50,51]

Selective nucleophilic substitution of 3-(bromoacetyl) coumarin **1** was accomplished through stirring with benzimidazole **9** in acetonitrile at ambient temperature afforded corresponding imidazole-1-carbonyl-chromenone **10** (Scheme 5).[52]

Valadbeigi *et al.*[53] reported the synthesis of thiazolidinedione derivatives **12** through heating of 3-(bromoacetyl)coumarin **1**



Scheme 2 Synthesis of aminomethyl-3-coumarinyl ketone hydrochloride **4**.



Scheme 3 Condensation of 3-(bromoacetyl)coumarin **1** with various heterocyclic amino groups.

with thiazolidine-2,4-dione **11** in alcoholic potassium hydroxide (Scheme 6).

The reaction of the 3-(bromoacetyl)coumarin derivatives **1** with substituted arylamine **13** in ethanol in the absence[54] or the presence of sodium bicarbonate[41,55,56] or under solvent-free condition using K_2CO_3 (ref. 57) yielded the corresponding 3-(2-(phenylanliino)acetyl)-2*H*-chromen-2-ones **14** (Scheme 7).

Whereas, refluxing of 3-(bromoacetyl)coumarin derivatives **1** with arylamines **13** in a mixture of ethanol and chloroform afforded the corresponding imino derivatives **15a-f** (Scheme 8).[54]

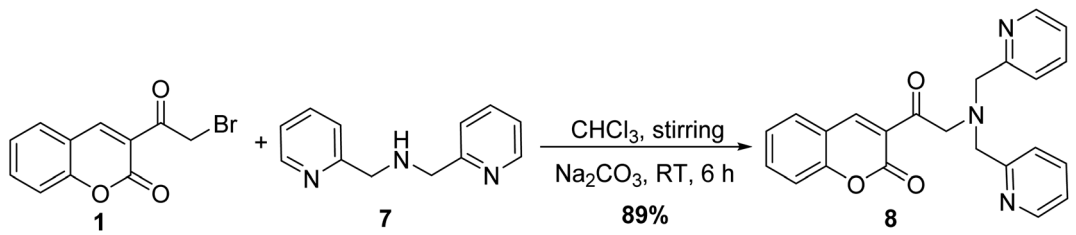
Coupling of 3-(bromoacetyl)coumarin derivatives **1** with amine hydrochlorides **16** such as hydroxylamine hydrochloride, methoxyamine hydrochloride, *o*-benzylhydroxylamine hydrochloride, and ethoxyamine hydrochloride in methyl alcohol to afford 3-(bromoacetyl) coumarin oximes **17** (Scheme 9).[53,58–62]

5.2. Azidation

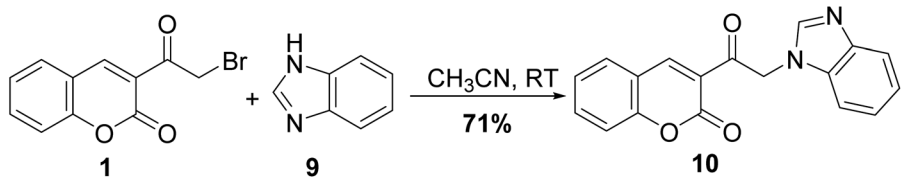
Evans and coworkers[58] reported the synthesis of coumarin fluorophore bearing an azidoacyl group **19** *via* the treatment of 3-(bromoacetyl)coumarin **1** with sodium azide (NaN_3) **18** at tetrahydrofuran (Scheme 10).

5.3. Thiocyanation reaction

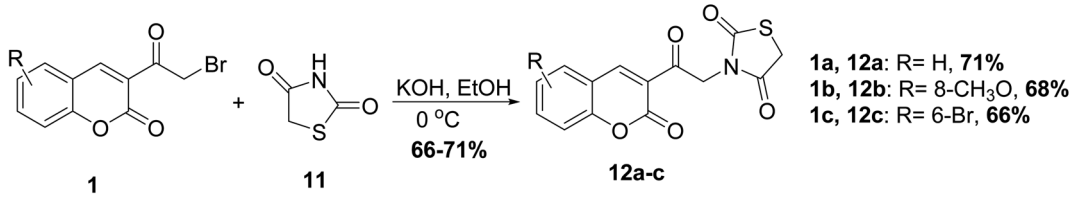
Ramanna *et al.*[63] reported the treatment of 3-(bromoacetyl) coumarin derivatives **1** with potassium thiocyanate (KSCN) **20**



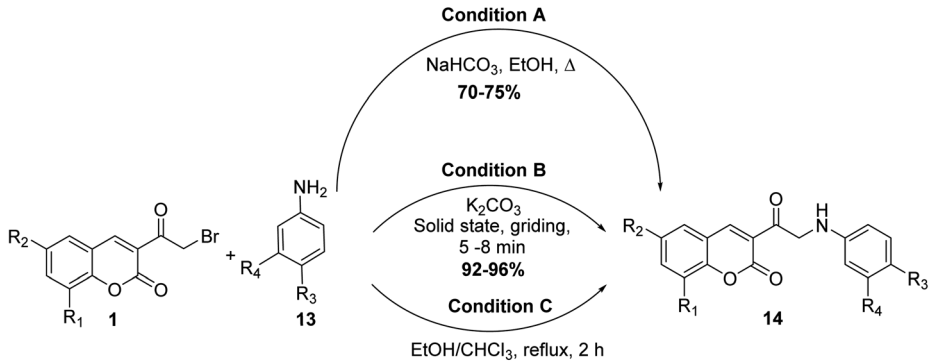
Scheme 4 Reaction of 3-(bromoacetyl)coumarin **1** and di(2-picolyl)amine **7**.



Scheme 5 Treatment of 3-(bromoacetyl)coumarin **1** with benzimidazole **9**.



Scheme 6 Transformation of 3-(bromoacetyl)coumarin **1** to thiazolidine-2,4-dione **11**.



Condition A

14aa) $R_1 = R_2 = R_3 = R_4 = H$

14ab) $R_1 = OH$, $R_2 = R_3 = H$, $R_4 = CO_2C_2H_5$

14ac) $R_1 = OCH_3$, $R_2 = R_3 = H$, $R_4 = CO_2H$

14ad) $R_1 = H$, $R_2 = Cl$, $R_3 = H$, $R_4 = CO_2H$

14ae) $R_1 = H$, $R_2 = OCH_3$, $R_3 = H$, $R_4 = CO_2H$

14af) $R_1 = OCH_3$, $R_2 = Cl$, $R_3 = H$, $R_4 = CO_2H$

14ag) $R_1 = OCH_3$, $R_2 = CH_2CH{=}CH_2$, $R_3 = H$, $R_4 = CO_2H$

Condition B

14ba) $R_1 = R_2 = R_3 = R_4 = H$

14bb) $R_1 = H$, $R_2 = Br$, $R_3 = R_4 = H$

14bc) $R_1 = R_2 = Br$, $R_3 = R_4 = H$

14bd) $R_1 = H$, $R_2 = Cl$, $R_3 = R_4 = H$

14be) $R_1 = Cl$, $R_2 = Cl$, $R_3 = R_4 = H$

14bf) $R_1 = R_2 = H$, $R_3 = Cl$, $R_4 = H$

Condition C

14ca) $R_1 = R_3 = H$, $R_2 = Br$, $R_4 = OCH_3$

14cb) $R_1 = R_4 = H$, $R_2 = Br$, $R_3 = OCH_3$

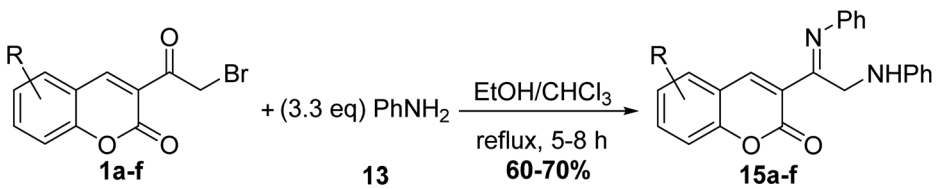
14cc) $R_1 = R_2 = Br$, $R_2 = H$, $R_3 = CH_3$

14cd) $R_1 = OCH_3$, $R_2 = R_4 = H$, $R_3 = CH_3$

14ce) $R_1 = OCH_3$, $R_2 = R_4 = H$, $R_3 = CH_3$

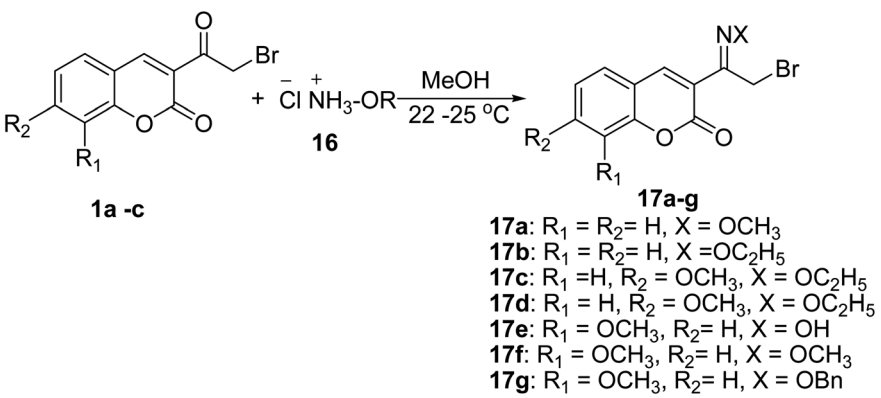
14cf) $R_1 = OCH_3$, $R_2 = R_4 = H$, $R_3 = Cl$

Scheme 7 Transformation of 3-(bromoacetyl)coumarins **1** to chromenones **14**.



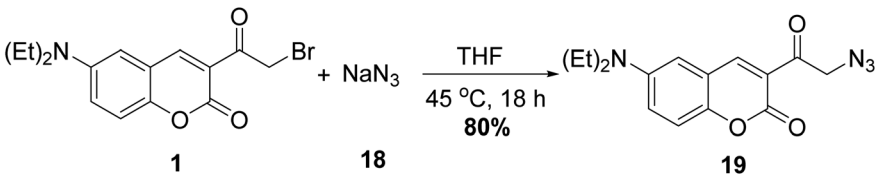
1a,15a: R= 6-Br
1b,15b: R= 6,8-diBr
1c,15c: R= 3-CH_3
1d,15d: R= 4-CH_3
1e,15e: R= 2-OCH_3
1e,15e: R= 3-OCH_3
1f,15f: R= 4-Cl

Scheme 8 Synthesis of imino derivatives **15**.

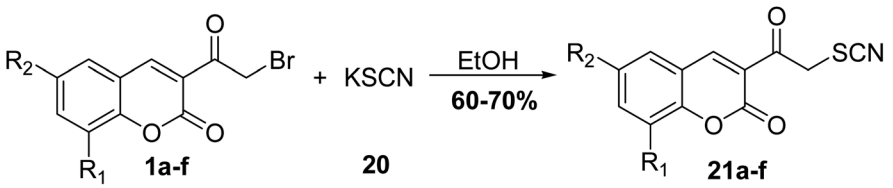


17a: $R_1 = R_2 = H$, X = OCH_3
17b: $R_1 = R_2 = H$, X = OC_2H_5
17c: $R_1 = H$, $R_2 = OCH_3$, X = OC_2H_5
17d: $R_1 = H$, $R_2 = OCH_3$, X = OC_2H_5
17e: $R_1 = OCH_3$, $R_2 = H$, X = OH
17f: $R_1 = OCH_3$, $R_2 = H$, X = OCH_3
17g: $R_1 = OCH_3$, $R_2 = H$, X = OBn

Scheme 9 Synthesis of bromoacetylcoumarin oximes **17**.

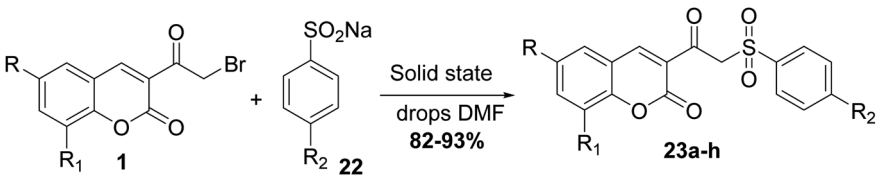


Scheme 10 Synthesis of 3-azidoacyl coumarins **19**.



1a,**21a**: R_1= R_2=H, **70%**
1b,**21b**:R_1= OCH_3, R_2=H, **68%**
1c,**21c**: R_1=Br, R_2 =H, **70%**
1d,**21d**: R_1 = Br, R_2 = Br, **64%**
1e,**21e**:R_1=H, R_2=Cl, **62%**
1f,**21f**: R_1=C, R_2=Cl, **60%**

Scheme 11 Treatment of 3-(bromoacetyl)coumarins **1a-f** with potassium thiocyanate **20**.



1a, 23a: R= R_1 = R_2 = H
1b, 23b: R= Br, R_1 = H
1c, 23c: R= R_1= Br, R_2 = H
1d, 23d: R= Cl, R_1 = R_2 = H
1e, 23e: R = R_1 = H, R_2= CH_3
1f, 23f: R = Br, R_1 = H, R_2 = CH_3
1g, 23g: R = R_1 = Br, R_2 = CH_3
1h, 23h: R = R_1 = Cl, R_2 = CH_3

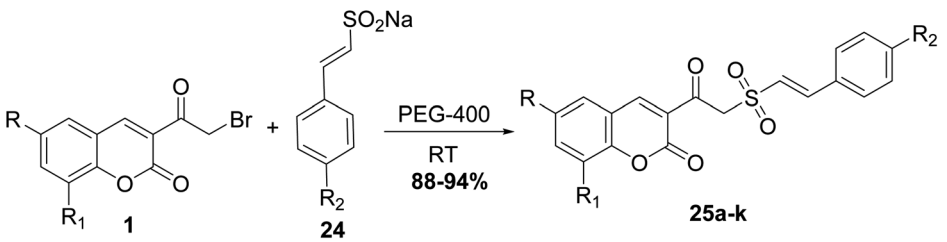
Scheme 12 Alkylation of 3-(bromoacetyl)coumarin derivatives **1** *via* sulfinates metal salts **22**.

in ethanol furnished 3-thiocyanatoacetyl coumarin derivatives **21** in good yields (Scheme 11).

5.4. Sulfonation reaction

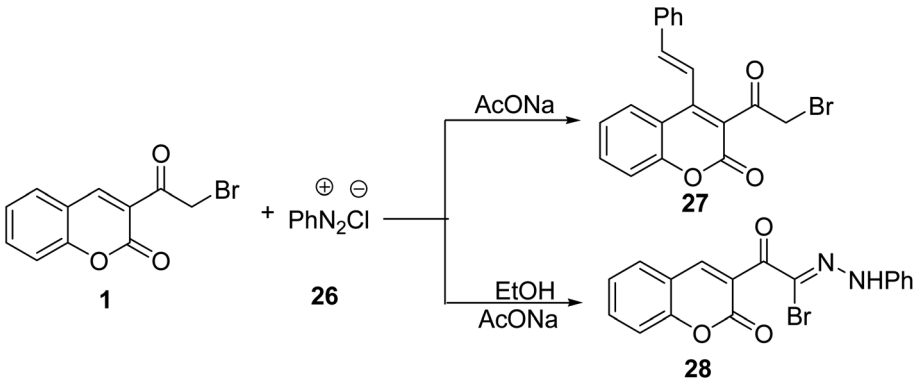
Mixing of 3-(bromoacetyl)coumarins **1** with sodium arene sulfinates **22** in solid state in the presence of few drops of DMF furnished 3-(2-(phenylsulfonyl)acetyl)coumarin derivatives **23** (Scheme 12).[64,65] Furthermore, the reactions of this type were promoted under solvent-free conditions, as reported in literature.[66,67]

A facile synthesis (*E*)-styryl sulfones **25a-k** was accomplished *via* the reaction of 3-(bromoacetyl)coumarin derivatives **1** with sodium sulfinates **24** in the presence of polyethylene glycol

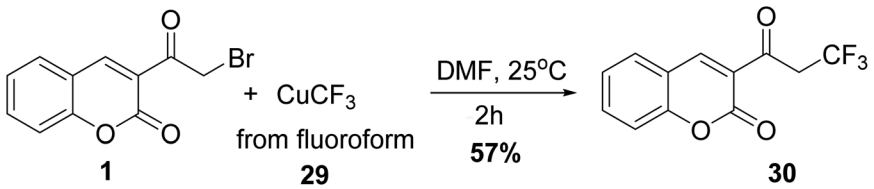


25a: R =R_1 = R_2 =H
25b: R =R_1 =H, R_2 = CH_3
25c: R = Br, R_1 =R_2 = H
25d: R = Br, R_1 = H, R_2 = CH_3
25e: R = R_1 = Br, R_2 = H
25f: R = R_1 =Br, R_2 = CH_3
25g: R = Cl, R_1 = R_2 = H
25h: R =R_1 = Cl, R_2 =CH_3
25j: R = Cl, R = R_2 = CH_3
25k: R= R_1 = Cl, R_2 = CH_3

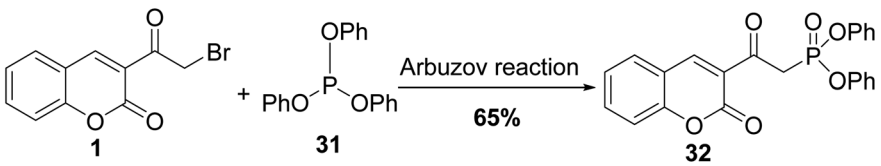
Scheme 13 Synthesis of heteryl (*E*)-styryl sulfone derivatives **25a-k**.



Scheme 14 Coupling 3-(bromoacetyl)coumarin **1** with benzendiazonium chloride **26**.



Scheme 15 Trifluoromethylation of 3-(bromoacetyl)coumarin **1**.



Scheme 16 Formation of 2-oxophosphonates **32**.

(PEG-400) for promoting the reaction at ambient temperature (Scheme 13).[68]

5.5. Coupling reactions

Coupling buffered solution of 3-(bromoacetyl)coumarin **1** with benzendiazonium chloride **26** yielded the corresponding 3-(2-bromoacetyl)-4-styryl-2*H*-chromen-2-one **27** (Scheme 14).[69] While the reaction of 3-(bromoacetyl)coumarin **1** with benzenediazonium chloride **26** under the influence of sodium acetate afforded *N*-phenylacetohydrazonoyl bromide bearing coumarin moiety **28** (Scheme 14).[70]

5.6. Trifluoromethylation reaction

Novak and co-workers showed that trifluoromethylation of 3-(bromoacetyl)coumarin **1** with CHF_3 **29** derived $CuCF_3$ at room temperature to give 2-trifluoromethylcoumarin **30** in yield 57% (Scheme 15).[71]

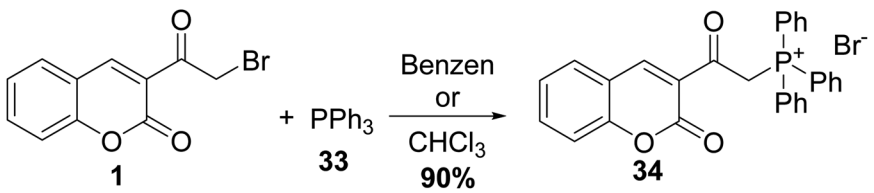
5.7. Phosphorylation reaction

3-(Bromoacetyl)coumarin **1** was transformed to 2-oxophosphonates **32** in xylene *via* Arbuzov reaction conditions with triphenyl phosphite **31** (Scheme 16).[72–75]

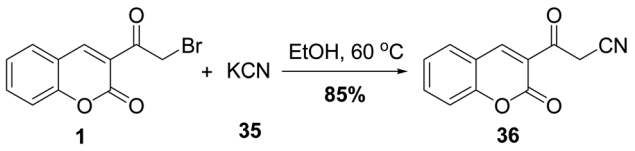
Wang *et al.* synthesized triphenylphosphonium **34** *via* the treatment of 3-(bromoacetyl)coumarin **1** with triphenylphosphine **33** in benzene or chloroform (Scheme 17).[76]

5.8. Cyanation reaction

3-(Cyanoacetyl)coumarin **36** was prepared based on cyanation of 3-(bromoacetyl)coumarin **1** by treatment with potassium cyanide (KCN) **35** under ethanolic condition (Scheme 18).[70]



Scheme 17 Treatment of 3-(bromoacetyl)coumarin **1** with triphenylphosphine **33**.



Scheme 18 Treatment of 3-(bromoacetyl)coumarin **1** with potassium cyanide **35**.

5.9. Reaction with active methylene compound

2-Hydroxy-1-(2-oxo-2*H*-chromen-3-yl-ethylidene)malononitrile **39** was obtained through Knoevenagel condensation of 3-(bromoacetyl)coumarin **1** with cyanoacetonitrile, **37** in the presence of ammonium acetate **38** (Scheme 19).[70]

5.10. Synthetic approach toward heterocyclic hybrids

5.10.1. Synthesis of three-membered rings with one heteroatom

5.10.1.1. Oxirane. Oxirane phosphonates **41** were obtained *via* Michaelis–Becker reaction of 3-(bromoacetyl)coumarin **1** and dialkyl phosphites **40** using *N*-benzyl-*N*,*N*,*N*-triethylammonium chloride (BTEAC) as a phase-transfer catalyst (Scheme 20).[77]

5.10.2. Synthesis of five-membered rings with one heteroatom

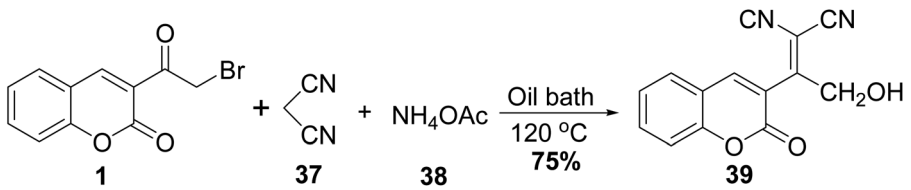
5.10.2.1. Pyrroles. An efficient synthesis of poly functionalized coumarin bearing pyrrolo[2,1-*a*]isoquinoline derivatives **44** was achieved *via* a multi-reaction of 3-(bromoacetyl)coumarin derivatives **1**, isoquinoline **42**, and dimethyl acetylenedicarboxylate **43** under the influence of triethylamine as catalyst (Scheme 21).[78]

Pal *et al.*[79] reported an eco-benign methodology for the preparation of coumarin-pyrrol hybrids **46** *via* three-component reactions of 3-(bromoacetyl)coumarin derivatives **1**, an alkyl/arylamine **13**, and acetylacetone **45** in the presence of optimized molarity of alum catalyst in water–PEG 400 (Scheme 22).

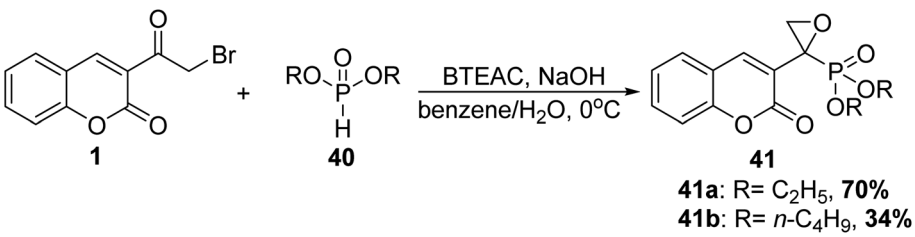
Pyrrole bis-coumarins **47** as fluorescent probes have been synthesized from the treatment of corresponding 3-(bromoacetyl)coumarin derivatives **1** with aniline **13** under catalytic condition (Zn–I_2) (Scheme 23).[80]

5.10.2.2. Dihydrofurans. The synthesis of coumarin substituted dihydrofurans **50a-i** in good yields was performed *via* refluxing 3-(bromoacetyl)coumarins **1**, dimedone **48**, and aromatic aldehydes **49** in a mixture of acetonitrile and pyridine as a solvent containing a catalytic amount of triethylamine (Scheme 24).[81]

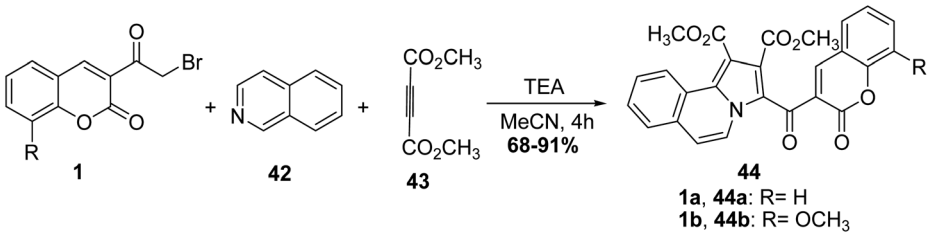
5.10.2.3. Thiophenes. Triethylamine-catalyzed heterocyclization of the ketene *N*,*S*-acetals **51** with 3-(bromoacetyl) coumarin **1** in ethanol has been employed to synthesize the corresponding 4-amino-2-phenylamino thiophenes **52a-c** (Scheme 25).[82]



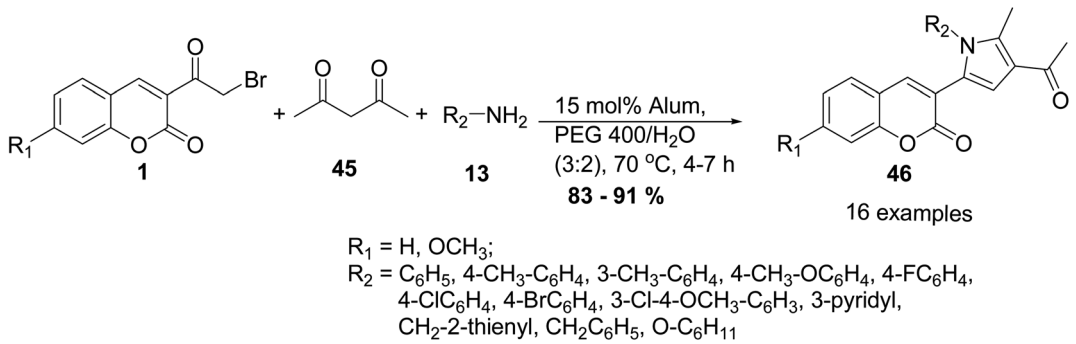
Scheme 19 Formation of 2-hydroxy((2*H*-chromen-3-yl)ethylidene)malononitrile **39**.



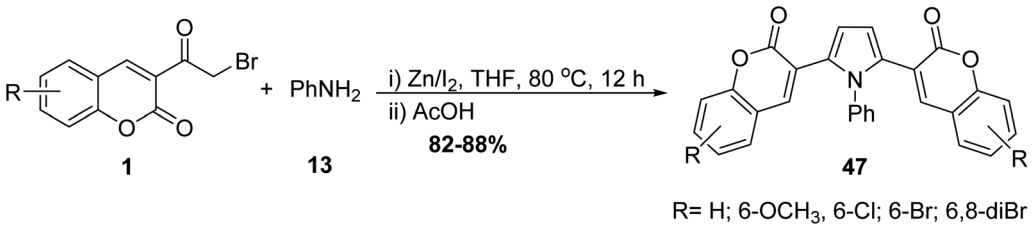
Scheme 20 Synthesis of enol phosphate **41**.



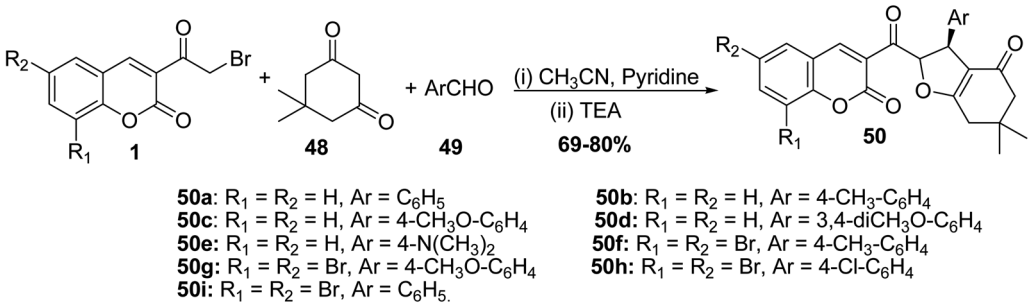
Scheme 21 Synthesis of coumarin bearing pyrrolo[2,1-*a*]isoquinolines **44**.



Scheme 22 MCR of coumarins **1**, an alkyl/arylamine **13**, and acetylacetone **45**.



Scheme 23 Reaction of corresponding 3-(bromoacetyl)coumarins **1** with aniline **13**.

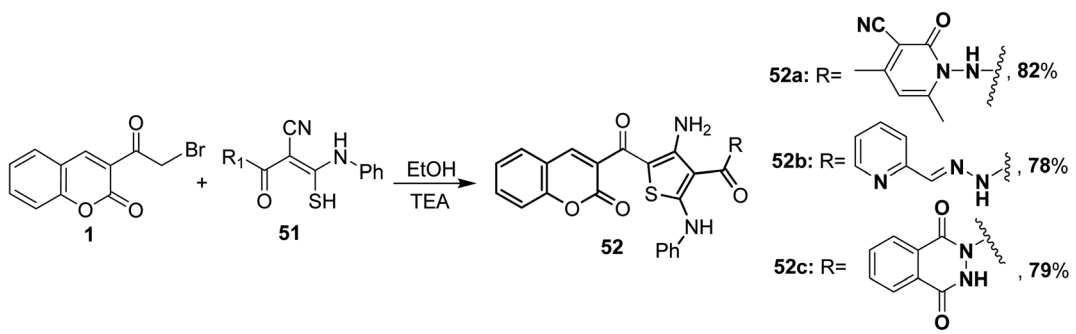


Scheme 24 Synthesis of coumarin bearing dihydrofurans.

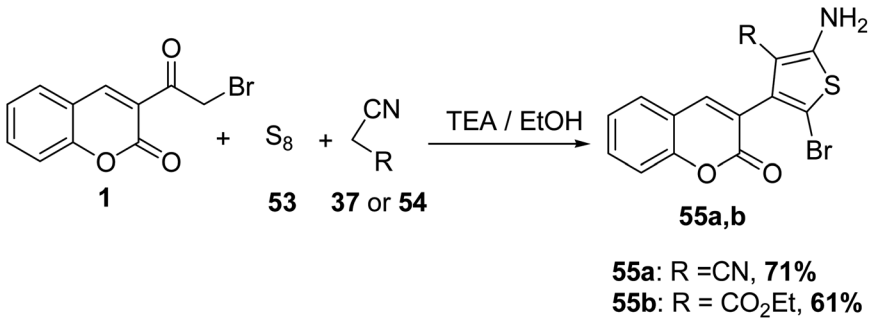
Treatment of 3-(bromoacetyl)coumarin **1** with sulfur **53** and either malononitrile **37** or ethyl cyanoacetate **54** in the presence of triethylamine furnished the corresponding 2-amino thiophene derivatives **55a** and **55b,** respectively (Scheme 26).[70]

5.10.3. Synthesis of five-membered rings with two heteroatoms

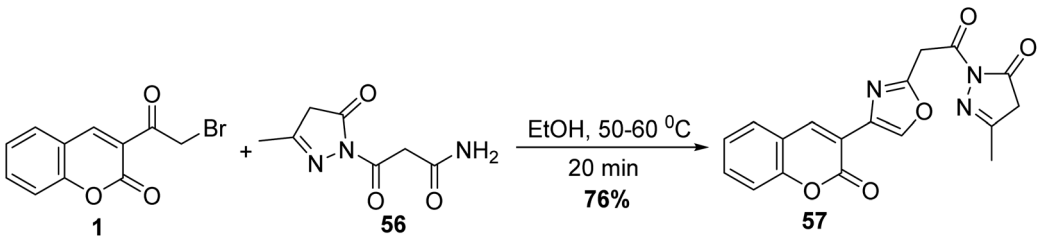
5.10.3.1. Oxazoles. Eco-friendly approach to accesses 3-methyl-1-(2-(4-(2-oxo-2*H*-chromen-3-yl)oxazol-2-yl)acetyl)-1*H*-pyrazol-5(4*H*)-one **57** was carried out without using any



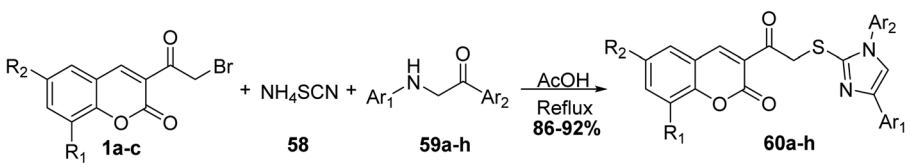
Scheme 25 Heterocyclization of the ketene *N,S*-acetals **51**.



Scheme 26 Formation of thiophene derivatives **55**.



Scheme 27 Synthesis of tetracyclic heterocyclic systems **57**.

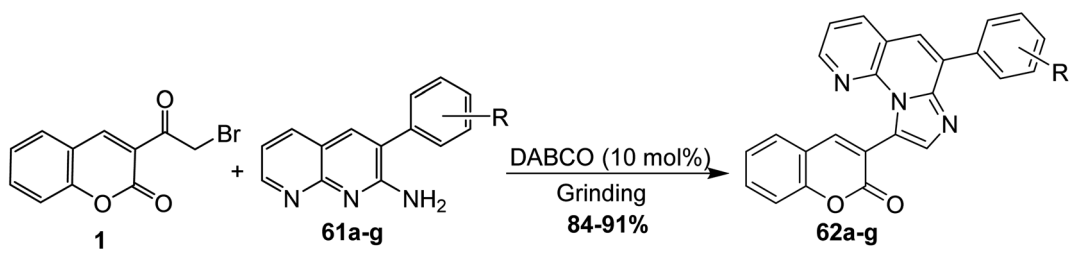


1a,60a: $R_1 = R_2 = H$, $Ar_1 = Ar_2 = 4\text{-Cl-}C_6H_4$
1a,60b: $R_1 = R_2 = H$, $Ar_1 = C_6H_5$, $Ar_2 = 4\text{-Cl-}C_6H_4$
1a,60c: $R_1 = R_2 = H$, $Ar_1 = C_6H_5$, $Ar_2 = 4\text{-Cl-}C_6H_4$
1a,60d: $R_1 = R_2 = H$, $Ar_1 = 4\text{-}NO_2\text{-}C_6H_4$, $Ar_2 = 4\text{-Cl-}C_6H_4$
1a,60e: $R_1 = R_2 = H$, $Ar_1 = 4\text{-}OCH_3\text{-}C_6H_4$, $Ar_2 = 4\text{-Cl-}C_6H_4$
1b,60f: $R_1 = Br$, $R_2 = Br$, $Ar_1 = 4\text{-Cl-}C_6H_4$, $Ar_2 = {}_4\text{-}OCH_3\text{-}C_6H_4$
1a,60g: $R_1 = R_2 = H$, $Ar_1 = 4\text{-Br-}C_6H_4$, $Ar_2 = 4\text{-Cl-}C_6H_4$
1c,60h: $R_1 = H$, $R_2 = Cl$, $Ar_1 = 4\text{-Cl-}C_6H_4$, $Ar_2 = {}_4\text{-}OCH_3\text{-}C_6H_4$

Scheme 28 Preparation of substituted imidazole derivatives **60**.

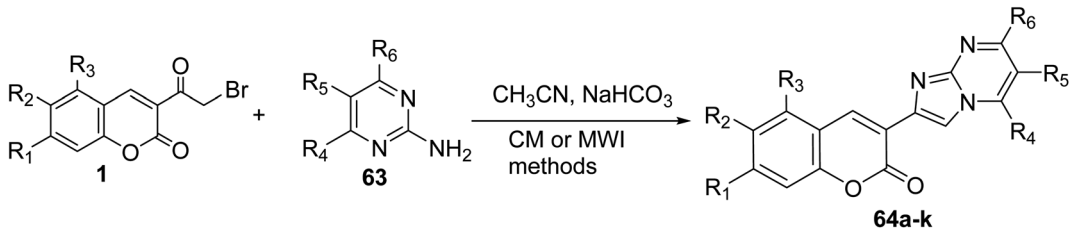
catalyst through the reaction of 3-(bromoacetyl)coumarin **1** with 3-oxopropanamide **56** in ethanol under heating (Scheme 27).[83]

5.10.3.2. Imidazole derivatives. A simple one-pot synthesis of novel substituted imidazoles **60** has been accomplished by three-component reaction of 3-(bromoacetyl)coumarin **1**,



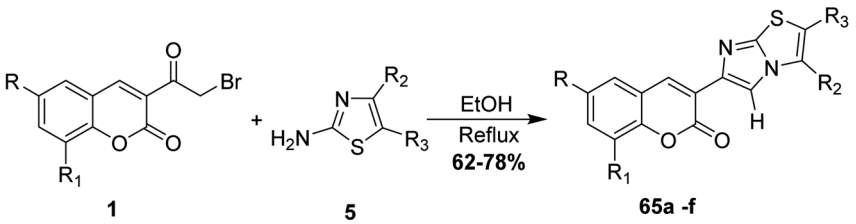
61a,62a: R =H
61b,62b: R = 4-F
61c,62c: R = 4-Br
61d,62d: R = 3-NO_2
61e,62e: R = 3-OH
61f,62f: R = 4-NO_2
61g,62g: R = 4-Cl

Scheme 29 Cyclocondensation of compound **1** and 2-amino-1,8-naphthyridines **61**.



64a: $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = H$
64b: $R_1 = N(C_2H_5)_2$; $R_2 = R_3 = R_4 = R_5 = R_6 = H$
64c: R_1 =H; $R_2 = R_3$= -CH=CH-CH=CH-; $R_4 = R_5 = R_6 = H$
64d: $R_1 = R_2 = R_3 = H$; $R_4 = CH_3$; $R_5 = H$; $R_6 = CH_3$
64e: $R_1 = N(C_2H_5)_2$; $R_2 = R_3 = R_4 = CH_3$; R_5=H; $R_6 = CH_3$
64f: $R_1 = H$; $R_2 = R_3$= -CH=CH-CH=CH-; $R_4 = CH_3$; $R_5 = H$; $R_6 = CH_3$
64g: $R_1 = R_2 = R_3 = H$; $R_4 = CH_3$; $R_5 = H$, R_6= Morpholinyl
64h: $R_1 = N(C_2H_5)_2$; $R_2 = R_3 = H$; $R_4 = CH_3$, R_5 =H; R = Morpholinyl
64i: R_1 =H; $R_2 = R_3$= -CH=CH-CH=CH-, $R_4 = CH_3$; R_5 =H; R_6= Morpholinyl
64j: $R_1 = R_2 = R_3$; R_4 =H; R_5 =Br; R_6= H
64k: $R_1 = N(C_2H_5)_2$; $R_2 = R_3 = R_4$ =H; R_5 = Br; R_6= H

Scheme 30 Synthesis of coumarin-imidazo[1,2-*a*]pyrimidines **64**.



65a: R= H, R_1= H, $R_2 = CH_2CO_2CH_3$, R_3 = H;
65b: R= H, R_1= H, R_2 = H, $R_3 = CH_3$
65c: R = Cl, R_1 =H , $R_2 = CH_2CO_2CH_3$; R_3 = H;
65d: R = Br, R_1 =H , $R_2 = CH_2CO_2CH_3$, R_3 = H;
65e: R = Br, R_1 =H , $R_2 = CH_2CO_2CH_3$; $R_3 = CH_3$
65f: R = Br, R_1 =Br , $R_2 = CH_2CO_2CH_3$; R_3 = H

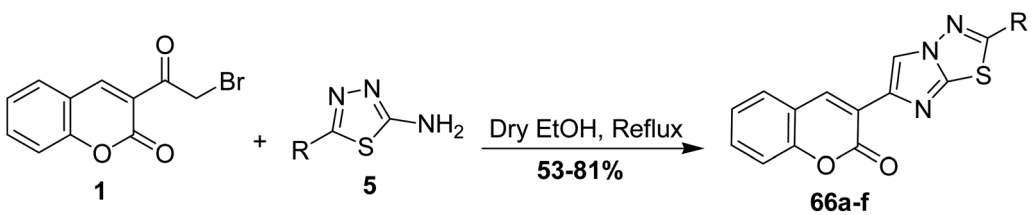
Scheme 31 Reaction of bromoacetylcoumarins **1** with thiazole derivatives **5**.

ammonium thiocyanate **58**, and phenacyl aniline **59** (Scheme 28).[84]

Boda *et al.* reported the preparation of fused imidazo[1,2-*a*][1,8]naphthyridines **62a-g** through the solvent-free reaction of 3-(bromoacetyl)coumarin **1** and 2-amino-1,8-naphthyridines **61a-g** using 1,4-diazabicyclo[2.2.2]octane (DABCO) as a catalyst (Scheme 29).[85]

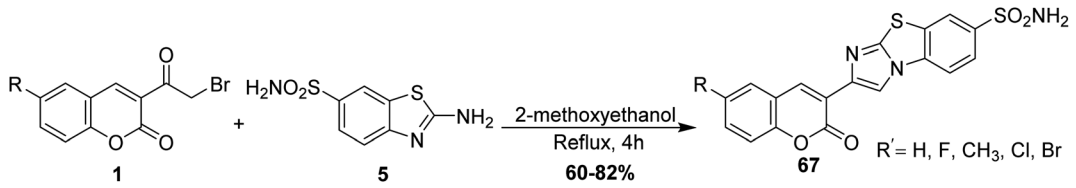
The coumarin-imidazo[1,2-*a*]pyrimidine derivatives **64** as pH-sensitive fluorescent compounds were carried out through thermal conventional (CM) or microwave irradiation (MWI) methods. Heating a mixture of 3-(bromoacetyl)coumarin **1** and 2-aminopyrimidine derivatives **63** in the microwave at 200 W at 100 °C afforded corresponding products in yields 5–90% compared by conventional thermal method (5–80%) (Scheme 30).[37]

Rao and Reddy have repeated the cyclocondensation of 3-(bromoacetyl)coumarins **1** with 2-aminothiazoles **5** in refluxing ethanol yielded the corresponding imidazo[2,1-*b*]thiazol-5-2*H*-chromen-2-ones **65** (Scheme 31).[86]

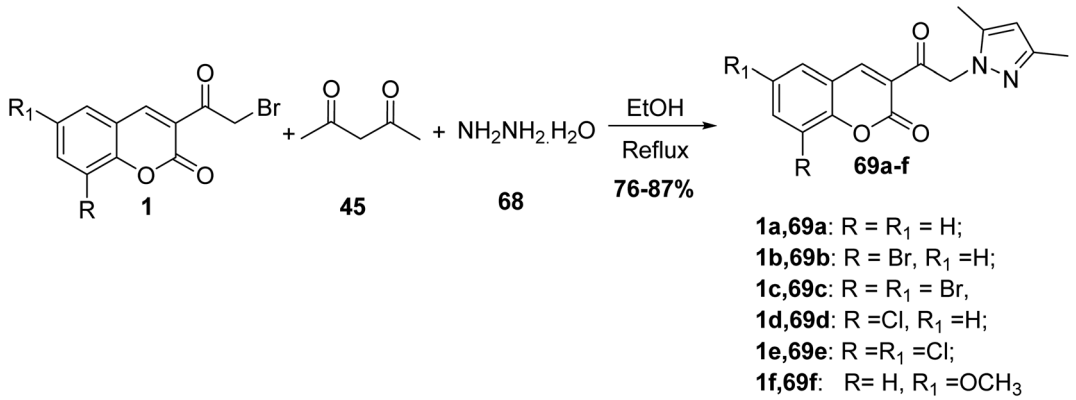


66a: R= C_2H_5, **66b**: R= *n*-C_3H_7, **66c**: R= cyclohexyl,
66d: R= C_6H_5, **66e**: R= 2-furyl, **66f**: R= 2-thienyl.

Scheme 32 Reaction of 3-(bromoacetyl)coumarin **1** and 1,3,4-thiadiazoles **5**.



Scheme 33 Formation of imidazobenzothiazoles **67**.



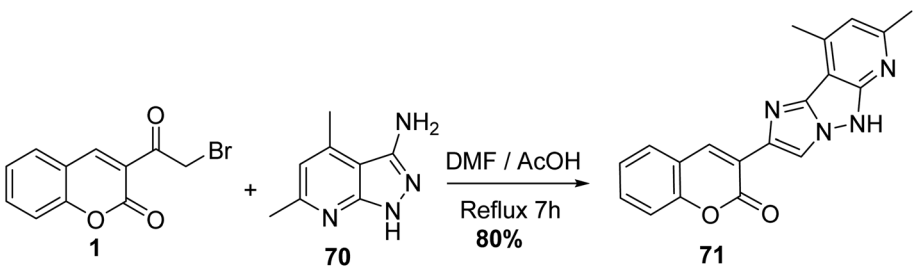
Scheme 34 Multi-component reaction of the synthesis of 3,5-dimethylpyrazoles **69**.

3-(2-Cyclohexylimidazo[2,1-*b*]-[1,3,4]thiadiazol-6-yl)-2*H*-chromen-2-ones **66a-f** was obtained as hydrobromide salt through the reaction of 3-(bromoacetyl)coumarin **1** with 2-amino-5-cyclohexyl-1,3,4-thiadiazole **5** in refluxing ethanol (Scheme 32).[87,88]

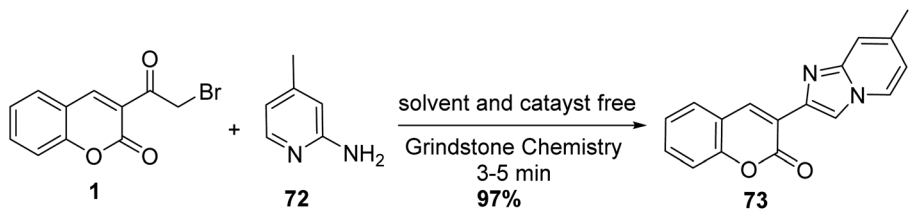
In refluxing 2-methoxyethanol, the reaction of 6-substituted-3-(bromoacetyl)coumarins **1** with 2-aminobenzo[*d*]thiazole-6-sulfonamide **5** was achieved, followed by neutralization using ammonia solution afforded corresponding imidazobenzothiazoles **67** (Scheme 33).[89]

5.10.3.3. Pyrazoles. 3,5-Dimethylpyrazole derivatives **69** have been prepared through a one-pot multi-component reaction of 3-(bromoacetyl)coumarin derivatives **1**, acetylacetone **45**, and hydrazine hydrate **68** in refluxing ethanol (Scheme 34).[90]

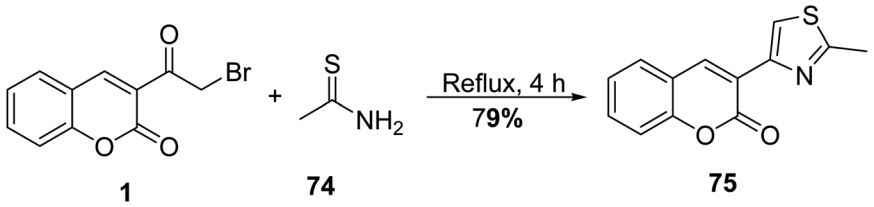
Condensation of 3-(bromoacetyl)coumarin **1** with 3-aminopyrazole **70** within DMF/AcOH yielded the corresponding imidazo[1,2-*b*]pyrazole **71** (Scheme 35).[91]



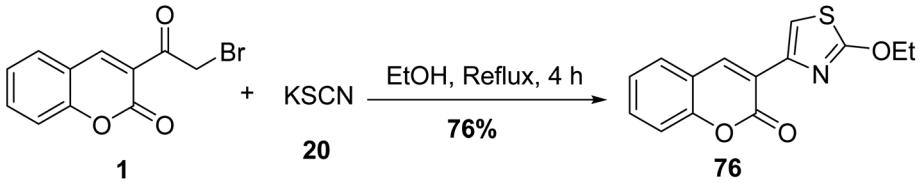
Scheme 35 Annulation of imidazo[1,2-*b*]pyrazole **71**.



Scheme 36 Synthesis of coumarin bearing imidazo[1,2-*a*]pyridine **73**.



Scheme 37 Formation of 3-(2-methylthiazol-4-yl)-2H-chromen-2-one **75**.



Scheme 38 Synthesis of 3-(2-ethoxythiazol-4-yl)-2*H*-chromen-2-one **76**.

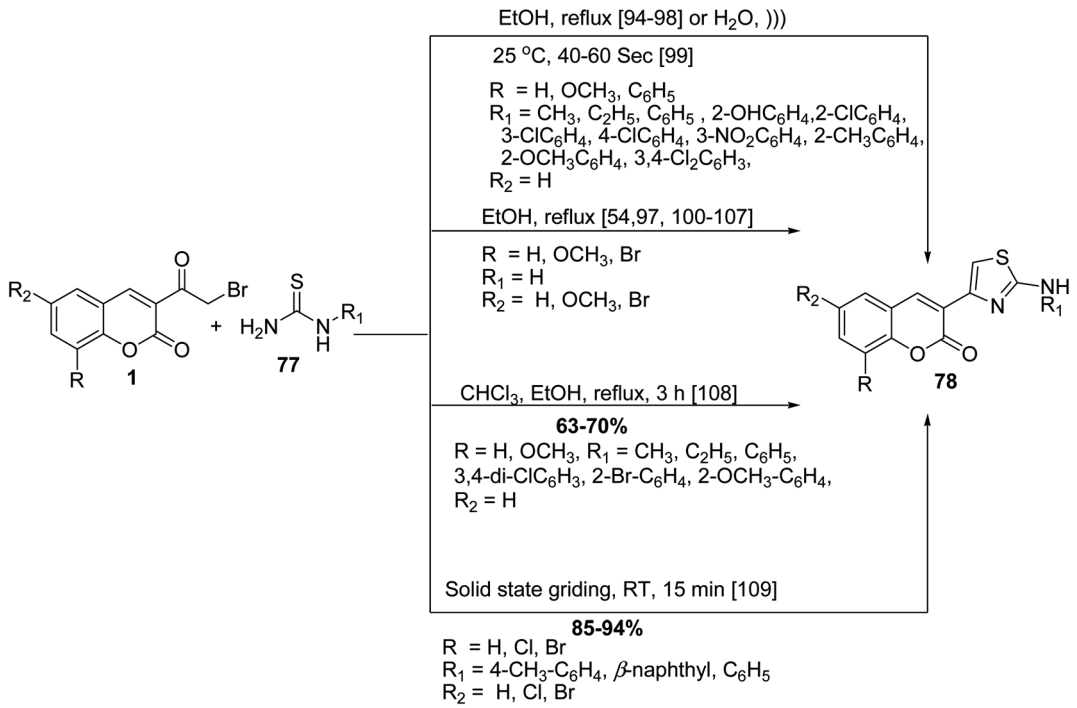
Using grindstone chemistry, the synthesis of 3-(7-methylimidazo[1,2-*a*]pyridin-2-yl)-2*H*-chromen-2-one **73** was achieved through the reaction of 3-(bromoacetyl)coumarin **1** with 2-amino-4-methylpyridine **72** under neat condition and catalyst-free (Scheme 36).[92]

5.10.3.4. Thiazole derivatives. Gouda disclosed the reaction of 3-(bromoacetyl)coumarin **1** with thioacetamide **74** in methanol under reflux furnished 3-(2-methylthiazol-4-yl)-2*H*-chromen-2-one **75** (Scheme 37).[93]

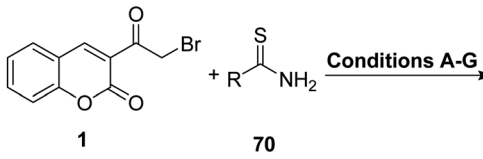
One of the most successful methods for the synthesis of 3-(2-ethoxythiazol-4-yl)-2*H*-chromen-2-one **76** is the refluxing 3-(bromoacetyl)coumarin **1** with potassium thiocyanate **20** in ethanol (Scheme 38).[78]

The Hantzsch thiazole synthesis of numerous 2-amino thiazolylcoumarins **78** was accomplished by cyclocondensation of 3-(bromoacetyl)coumarin derivatives **1** with various *N*-substituted thiourea **77** under various conditions (Scheme 39).[54,94–109]

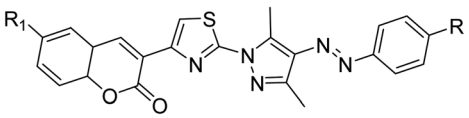
Analogously, 4-coumarinylthiazole derivatives **79–85** were efficiently prepared under conventional method or ultrasound irradiation in short reaction and high yields *via* the condensation of various 3-(bromoacetyl)coumarin derivatives **1** with *N*-substituted thioamide **74** (*e.g.* 2,4-thioureido



Scheme 39 Hantzsch route for the synthesis of substituted 2-amino thiazolylcoumarins **78**.

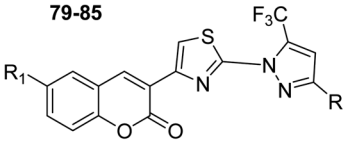


1 70 **Conditions A-G** **79-85**



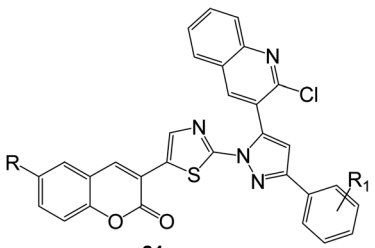
79a -g

Condition A: EtOH,Na_2CO_3, reflux [110]
79a: R=Cl, R_1= H
79b: R= Br, R_1= Cl
79c: R= CH_3, R_1= H
79d: R= CH_3, R_1= Cl
79e: R= Br, R_1=H
79f: R= Cl, R_1= Cl
79g: R= H, R_1= H



80a-g

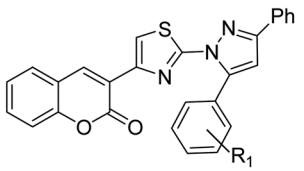
Condition B: EtOH,Na_2CO_3, reflux [111]
80a: R_1=H, R_2= CF_3
80b: R_1= Cl, R_2= CF_3
80c: R_1= H, R_2= 4-ClC_6H_4
80d: R_1= Br, R_2= 4-ClC_6H_4
80e: R_1= Cl, R_2= 4-BrC_6H_4
80f: R_1= H, R_2= 4-BrC_6H_4
80g: R_1= Br, R_2= 4-FC_6H_4



81a-y

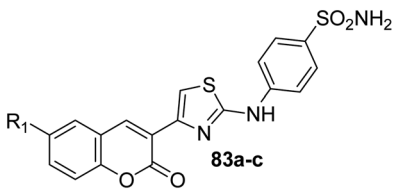
Condition C: EtOH, reflux, 1-3 h [112]

82a) R= H, R_1 = 2-Cl; **82b**) R= H, R_1 = 2-F;
82c) R= H, R_1 = 3-F; **82d**) R= H, R_1 = 4-F;
82e) R= H, R_1 = 4-NO_2; **82f**) R= Cl, R_1 = 2-Cl;
82g) R= Cl, R_1 = 2-F; **82h**) R= Cl, R_1 = 3-F;
82i) R= Cl, R_1 = 4-F; **82j**) R= Cl, R_1 = 4-NO_2;
82k) R= Br, R_1 = 2Cl; **82l**) R= Br, R_1 = 2-F;
82m) R= Br, R_1 = 3-F; **82n**) R= Br, R_1 = 4-F;
82o) R= Br, R_1 = 4-NO_2; **82P**) R= F, R_1 = 2-Cl;
82q) R= F, R_1 = 2-F; **82**r) R= F, R_1 = 3-F;
82s) R= F, R_1 = 4-F; **82t**) R= F, R_1 = 4-NO_2;
82u) R= I, R_1 = 2-Cl; **82v**) R= I, R_1 = 2-F;
82w) R= I, R_1 = 3-F; **82x**) R= I, R_1 = 4-F;
82y) R= I, R_1 = 4-NO_2;



82 a-d

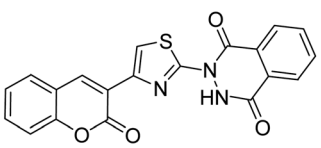
Condition D: EtOH, reflux, 1-3 h [113]
82a: 3-BrC_6H_4
82b: 3-$CH_3OC_6H_4$
82c: 4-$CH_3C_6H_4$
82d: 4-$CH_3OC_6H_4$



83a-c

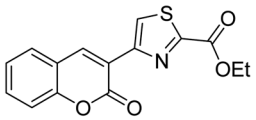
Condition E: AcONa/ EtOH: THF, reflux, 2h [114]

83a: H; **83b**: Cl; **83c**: Br



84 (84%)

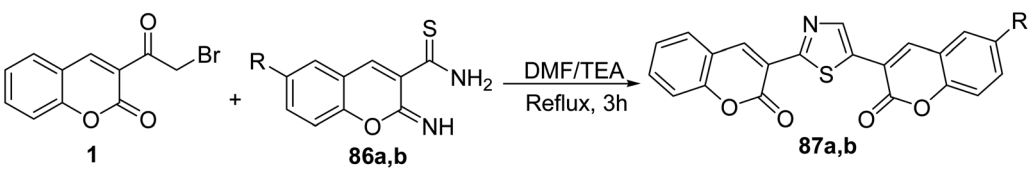
Condition F: US, EtOH, 40 min [115]



85 (63%)

Condition G: EtOH, 80 ^{0}C, 5 h [116]

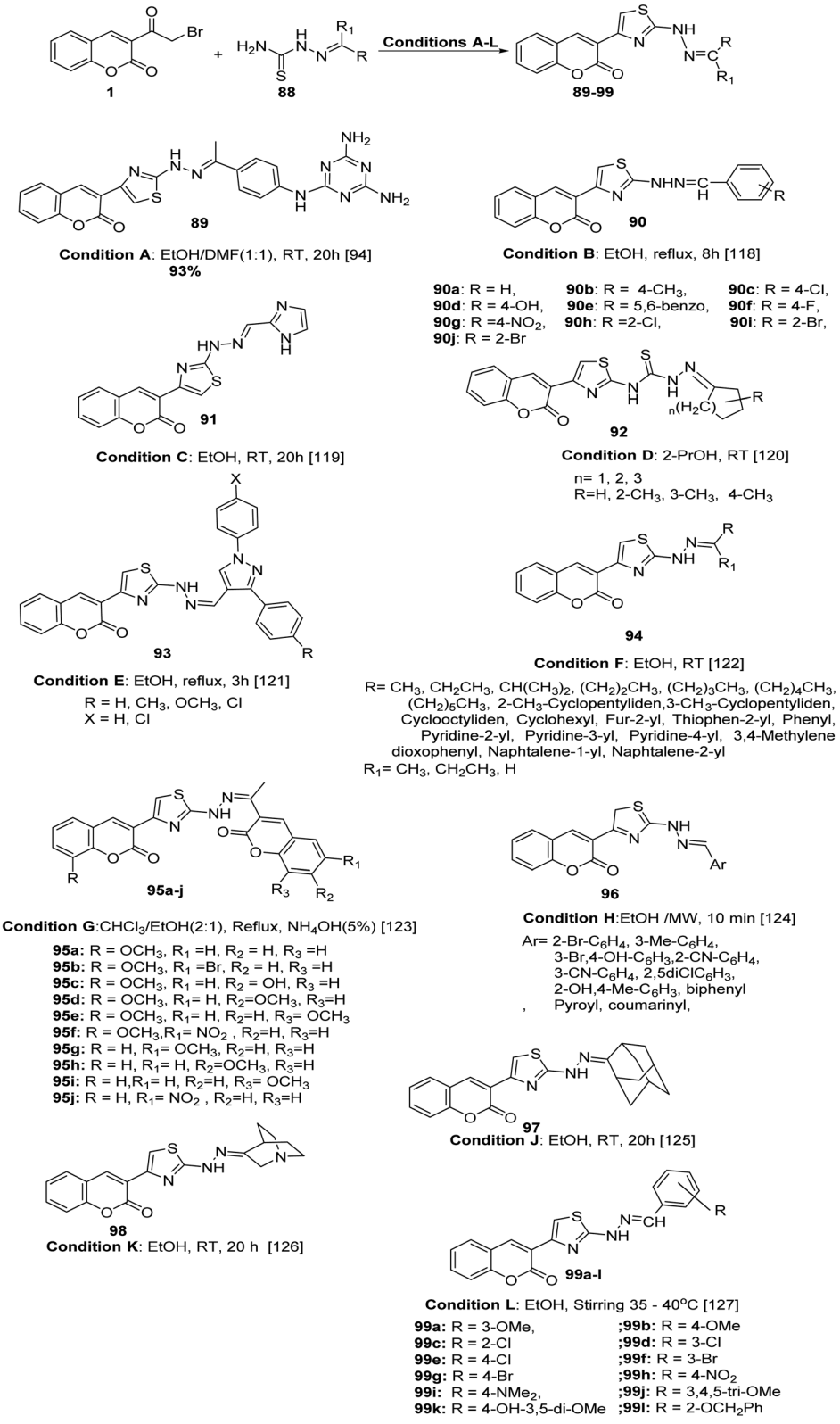
Scheme 40 Treatment of various 3-(bromoacetyl)coumarins **1** with *N*-substituted thioamides **74**.



1 **86a,b** **87a,b**

86a, 87a: R= 4-$CH_3C_6H_3S$-CH_2^-, **79%**
86b, 87b: R= $CH_2N(C_2H_5)_2$, **74%**

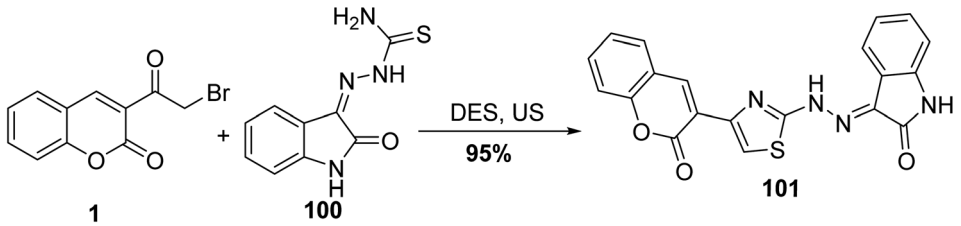
Scheme 41 Synthesis of 3-(thiazol-2-yl)-2*H*-chromen-2-ones **87a,b**.



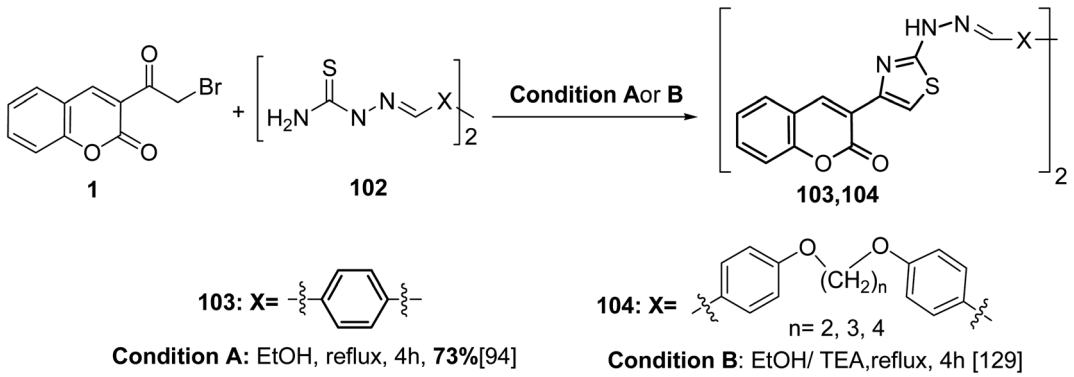
Scheme 42 Synthesis of series of hydrazinyl thiazolyl coumarin derivatives 89–99.

benzenesulfonamide, ethyl thiooxamate, dihydrophthalazine carbothioamide, and pyrazole carbothiamides) in refluxing ethanol or tetrahydrofuran under alkaline condition (sodium acetate and sodium carbonate) (Scheme 40).[110–116]

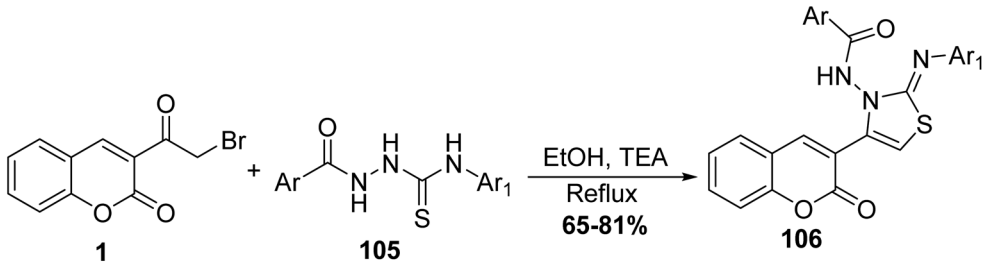
3-(Bromoacetyl)coumarin **1** was reacted with the appropriate carbothioamides **86** in DMF in the presence of triethylamine to give the corresponding 3,3′-(thiazole-2,4-diyl)bis-chromen-2-ones **87a,b** (Scheme 41).[117]



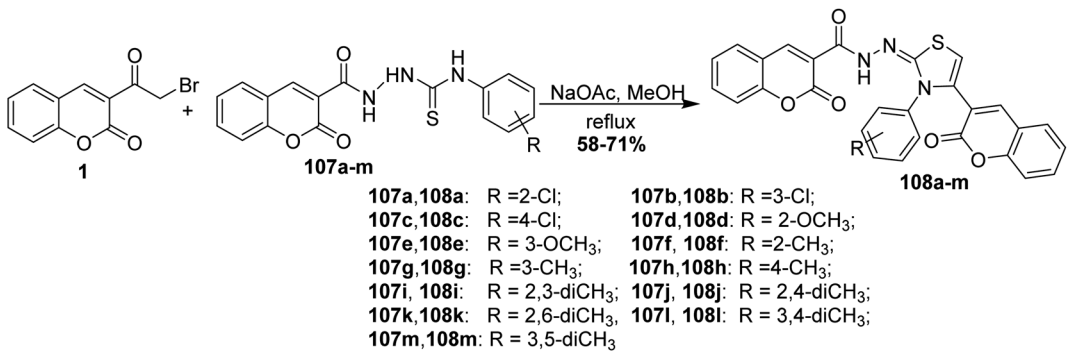
Scheme 43 The synthesis of 2-oxochroman-3-thiazol-2-hydrazono-indolin-2-one **101**.



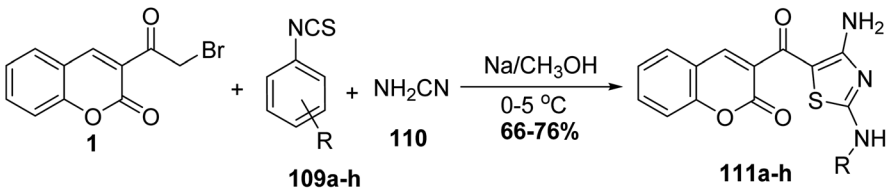
Scheme 44 Formation of bis(thiazole-4,2-diyl)bis(2*H*-chromen-2-ones) **103** and **104**.



Scheme 45 Synthesis of thiazolylcoumarin derivatives **106**.



Scheme 46 Synthesis of bis-coumarin–iminothiazole hybrids **108a-m**.



109a,**111a**: R= C_6H_5,
109b,**111b**: R= 4-$OCH_3C_6H_5$,
109c,**111c**: R= 3,4,5-$(OCH_3)_3C_6H_2$,
109d,**111d**: R= pyrrolidin-1yl,
109e,**111e**: R= 4-benzylpiperidin-1-yl,
109f,**111f**: R= 4-phenylpiperazin-1-yl,
109g,**111g**: R= morphilino,
109h,**111h**: R= thiomorphilino

Scheme 47 The synthesis of (4-aminophenyl-thiazole-5-carbonyl)-2*H*-chromenones **111**.

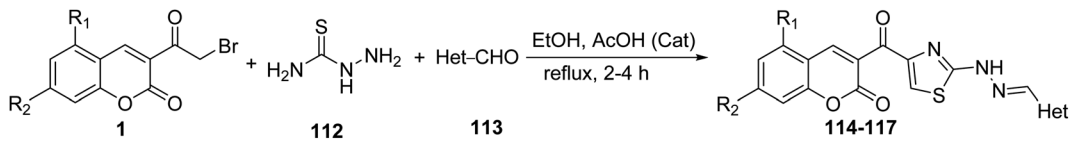
New sets of hydrazinyl thiazolyl coumarin derivatives **89–99** were accomplished in high and efficient yield from the one-pot Hantzsch reaction; the proposed mechanism of the reaction involves the cyclocondensation of the appropriate thiosemicarbazones **88** with 3-(bromoacetyl)coumarin **1** under various conditions (Scheme 42).[94,118–127]

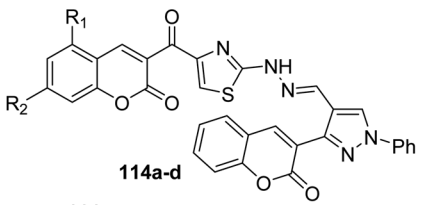
Utilizing deep eutectic solvent (DES) and ultrasound for the preparation of 2-oxochroman-3-thiazol-2-hydrazono-indolin-2-one **101** *via* the reaction of **1** with hydrazinecarbothioamide **100** (Scheme 43).[94,128]

The bis(thiazole-4,2-diyl)bis(2*H*-chromen-2-ones) **103** and **104** were obtained *via* one-pot cyclisation reaction of bis(hydrazinecarbothioamides) **102** with 3-(bromoacetyl)coumarin **1** (Scheme 44).[94,129]

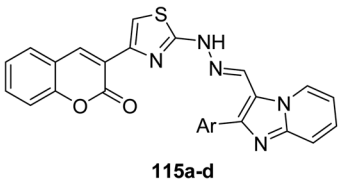
Cyclization reaction of 3-(bromoacetyl)coumarin **1** with thiosemicarbazides **105** in the presence of a catalytic amount of trimethylamine in ethanol yielded thiazolylcoumarin derivatives **106** (Scheme 45).[130]

Refluxing of 3-(bromoacetyl)coumarin **1** and coumarinothiosemicarbazides **107a-m** in methanol containing drops of

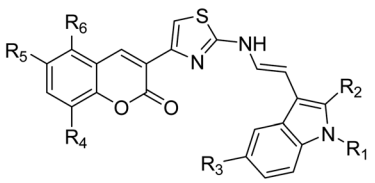




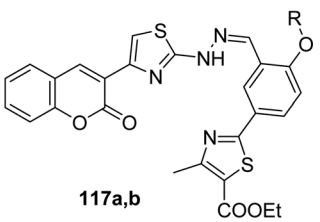
114a: R_1= R_2 = H
114b: R_1= H, R_2=Cl
114c: R_1= H, R_2=Br
114d: R_1= R_2=Br



115a: Ar = 4-Br-C_6H_4
115b: Ar = 4-Cl-C_6H_4
115c: Ar = 4-NO_2-C_6H_4
115d: Ar = 4-OCH_3-C_6H_4

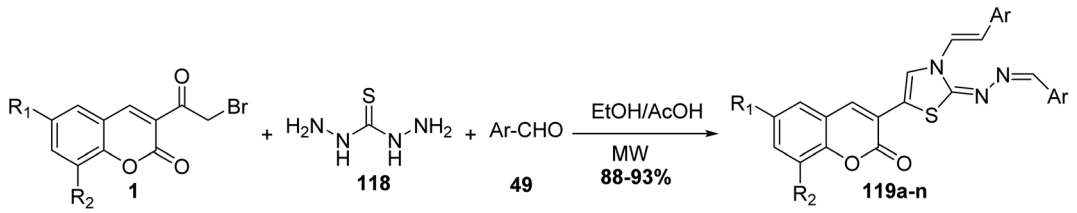


116a: R_1 = H, C_2H_5
116b: R_2 = H, CH_3
116c: R_3 = H, Br, OCH_3
116d: R_4 = H, Br
116e: R_5= H, Br, Cl
116f: R_6 = H, Br



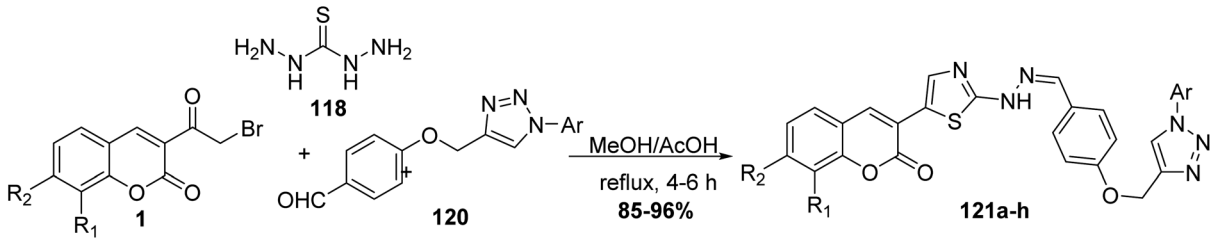
117a: R= H
117b: R= *iso*butyl

Scheme 48 Formation of annulated thiazolylcoumarins **114–117**.



119a: R_1=H, R_2= H, Ar= 4-Cl-C_6H_4
119b: R_1=H, R_2= H, Ar= 4-Br-C_6H_4
119c: R_1=Cl, R_2= H, Ar= 4-Cl-C_6H_4
119d: R_1=Cl, R_2=Cl, Ar= C_6H_5
119e: R_1=Cl, R_2= Cl, Ar= 4-Cl-C_6H_4
119f: R_1=Cl, R_2= Cl, Ar= 4-Br-C_6H_4
119g: R_1=Br, R_2= H, Ar= 4-Cl-C_6H_4
119h: R_1=Br, R_2= H, Ar= 4-Br-C_6H_4
119i: R_1=Br, R_2= Br, Ar= 4-Cl-C_6H_4
119j: R_1=Br, R_2= Br, Ar= 4-Br-C_6H_4
119k: R_1= H, R_2= OCH_3, Ar= 4-Cl-C_6H_4
119l: R_1= H, R_2= OCH_3, Ar= 4-Br-C_6H_4
119m: R_1= Br, R_2=OCH_3, Ar= 4-Cl-C_6H_4
119n: R_1= Br, R_2= OCH_3,Ar= 4-Br-C_6H_4

Scheme 49 Synthesis of coumarin based thiazoles **119a-n**.



1a,121a: R_1= H, R_2= H; Ar= 4-OCH_3-C_6H_4
1b,121b: R_1= H, R_2= OC_6H_5; Ar= 4-OCH_3-C_6H_4
1c,121c: R_1= OCH_3, R_2= H; Ar= 4-OCH_3-C_6H_4
1d,121d: R_1= OCH_3, R_2= Br; Ar= 4-OCH_3-C_6H_4
1e,121e: R_1=OC_6H_5, R_2= Br; Ar= 4-OCH_3-C_6H_4
1f,121f: R_1=Cl, R_2= Cl; Ar= 4-OCH_3-C_6H_4
1g,121g: R_1=Br, R_2= Br; Ar= 4-OCH_3-C_6H_4
1h,121h: R_1=NO_2, R_2= NO_2; Ar= 4-OCH_3-C_6H_4

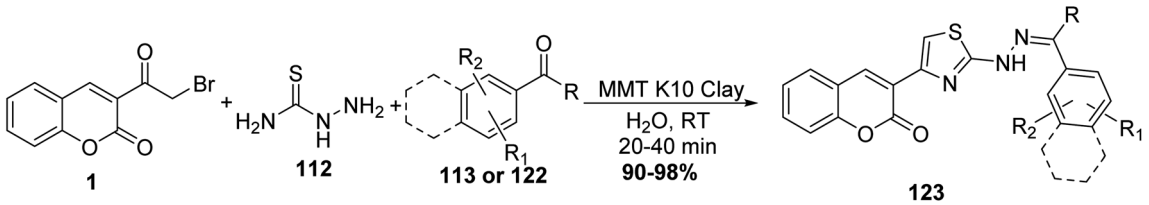
Scheme 50 Synthetic route for the formation of 1,2,3-triazole-thiazole systems **121a-h**.

acetic acid as catalyst gave bis-coumarin–iminothiazole hybrids **108a-m** in good yields (Scheme 46).[131]

The multi-component reaction of 3-(bromoacetyl)coumarin derivatives **1,** phenylisothiocyanates **109a-h** with cyanamide **110** in freshly prepared sodium methoxide yielded annulated 3-(4-amino-2-(phenylamino)thiazole-5-carbonyl)-2*H*-chromen-2-one derivatives **111a-h** in moderate yields (Scheme 47).[132]

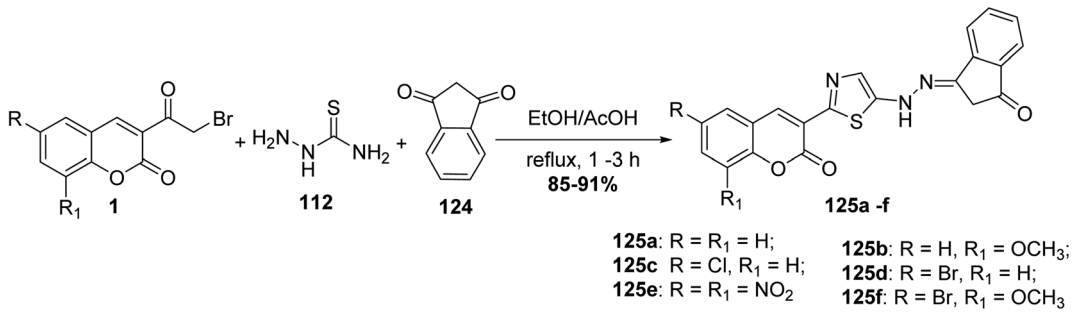
Novel series of thiazolylcoumarins **114-117** were prepared *via* multi-component condensation reaction of 3-(bromoacetyl) coumarin derivatives **1** thiosemicarbazide **112** and aldehydes **113** with different substitution patterns (aryl,[133,134] pyrazole,[134] imidazo[1,2-*a*]pyridine,[135] indole[136]) in ethanol with a catalytic amount of acetic acid (Scheme 48).

New series of coumarin based thiazoles **119a-n** were accomplished *via* mixing of substituted 3-(bromoacetyl) coumarins **1,** aldehydes **49,** and thiocarbohydrazide **118** in the presence of a catalytic amount of acetic acid in the microwave for 6–8 min (Scheme 49).[137]

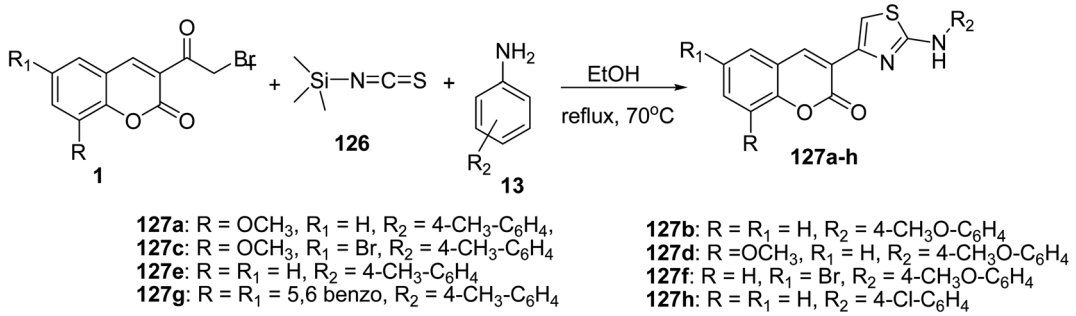


R = H, CH_3, Ph
R_1 = CH_3, OCH_3, OC_2H_5, OH, OPh, NH_2, NO_2, CN, Cl, Br, F;
R_2 = H, Cl, Br; OCH_3, OH

Scheme 51 Formation of thiazolyl coumarins **123**.



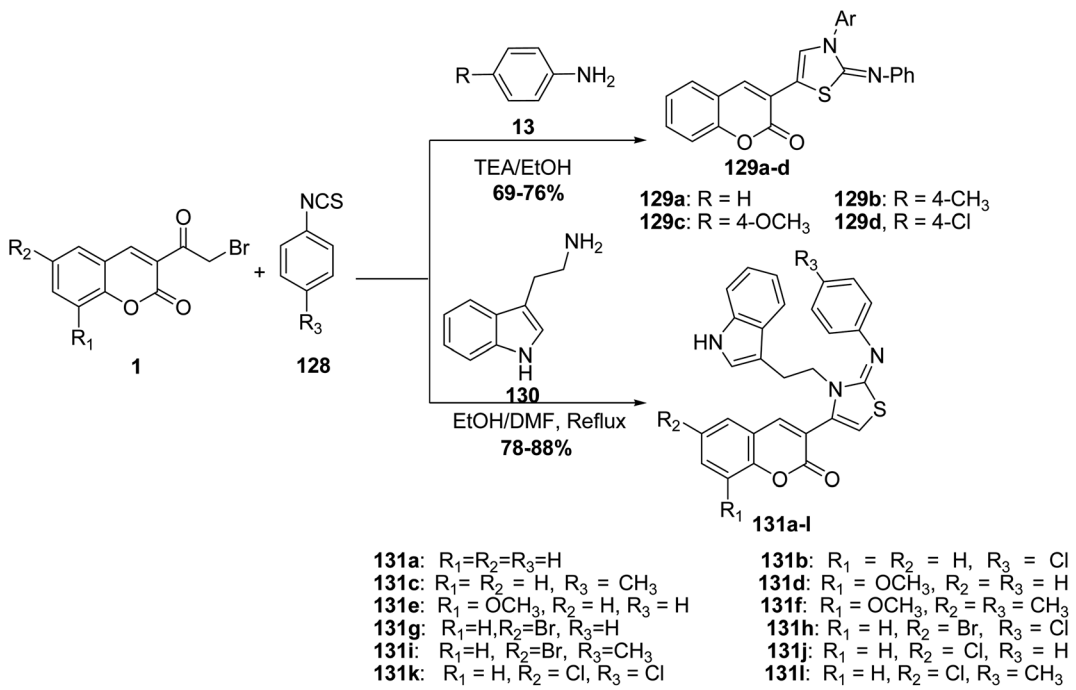
Scheme 52 Synthesis of novel thiazolylhydrazone derivatives **125**.



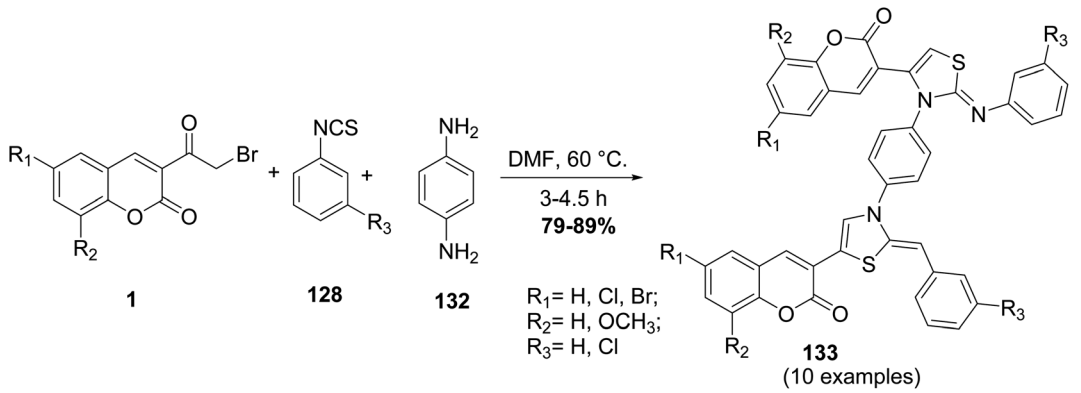
Scheme 53 Synthesis of 3-(2-amino-4-thiazolyl)coumarins **127a-h**.

Three-component condensation of 3-(bromoacetyl)coumarin derivatives **1**, thiocarbohydrazide **118** and aldehyde **120** were carried out under refluxing condition in ethanol in the presence of a catalytic amount of acetic acid to afford novel series of substituted 1,2,3-triazole-hydrazinyl-1,3-thiazole scaffolds **121a-h** (Scheme 50).[138]

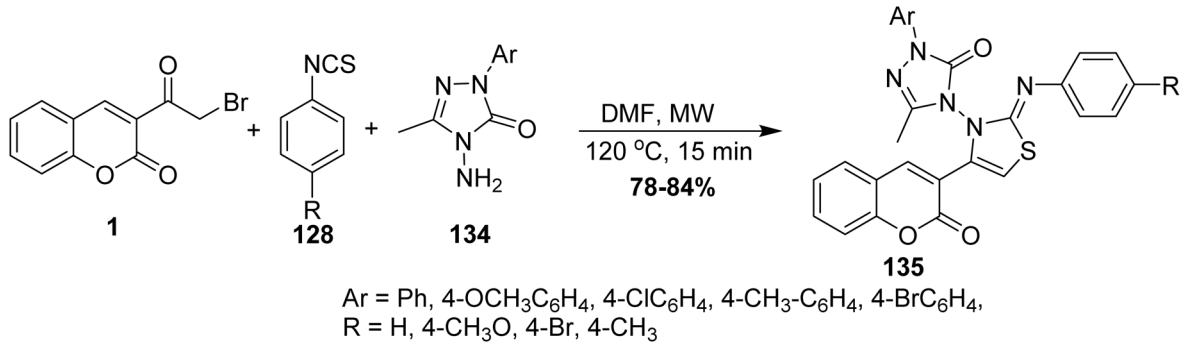
A water-mediated MCR protocol has been described for the synthesis of thiazolyl coumarins **123** from a three-component reaction of 3-(bromoacetyl)coumarin **1**, aldehydes **113** or ketones **122**, and thiosemicarbazide **112** catalyzed by montmorillonite K10 clay at ambient temperature (Scheme 51).[139]



Scheme 54 Synthesis of 2-arylimino-3-thiazolines **129** and **131**.



Scheme 55 Preparation of bis (thiazolyl-2*H*-chromene) systems **133**.

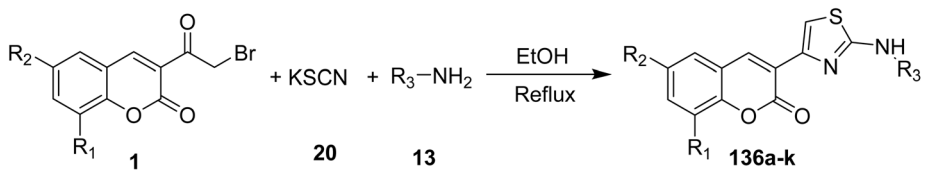


Scheme 56 Preparation of poly functionalized heterocyclic hybrids **135**.

One-pot, synthesis of thiazolylhydrazone derivatives **125a-f** through multi-component condensation of 3-(bromoacetyl) coumarin derivatives **1**, thiosemicarbazide **112** and 1,3-indandione **124** in refluxing ethanol using a catalytic amount of acetic acid (Scheme 52).[140]

Multi-component synthesis of 3-(2-amino-4-thiazolyl) coumarins **127a-h** have been obtained in good yields by refluxing of 3-(bromoacetyl)coumarin derivatives **1**, trimethylsilyl isothiocyanate **126**, and different primary amines **13** in ethanol (Scheme 53).[141]

The reaction of 3-(bromoacetyl)coumarins **1** with phenylisothiocyanate **128** and aniline derivatives **13** afforded the thiazole derivatives **129a–d** (Scheme 54).[70] On the other hand, an efficient three-component synthesis of 2-arylimino-3-



136a: $R_1 = R_2 = H$, $R_3 = CH_3\text{-}C_6H_4$ **136b**: $R_1 = R_2 = H$, $R_3 = C_6H_5$

136c: $R_1 = H$, $R_2 = Cl$, $R_3 = CH_3\text{-}C_6H_4$ **136d**: $R_1 = H$, $R_2 = Cl$, $R_3 = C_6H_5$

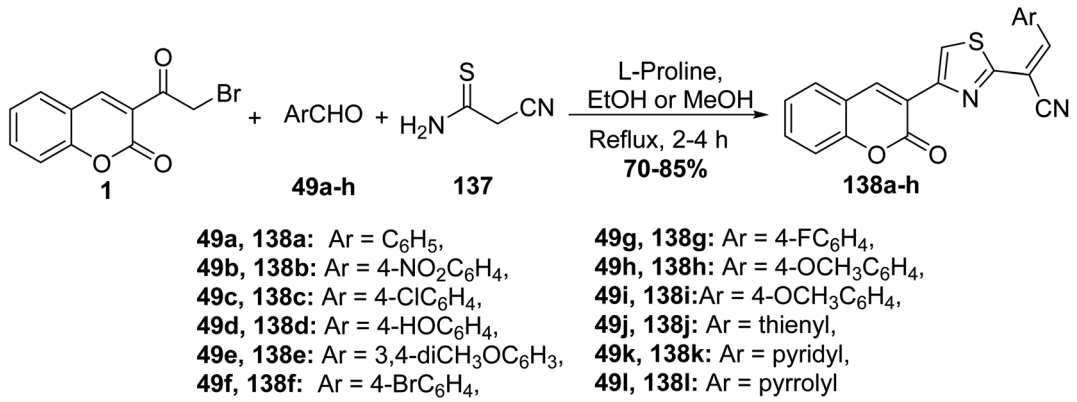
136e: $R_1 = R_2 = Cl$, $R_3 = CH_3\text{-}C_6H_4$ **136f**: $R_1 = R_2 = Cl$, $R_3 = C_6H_5$

136g: $R_1 = H$, $R_2 = Br$, $R_3 = CH_3\text{-}C_6H_4$ **136h**: $R_1 = H$, $R_2 = Br$, $R_3 = C_6H_5$

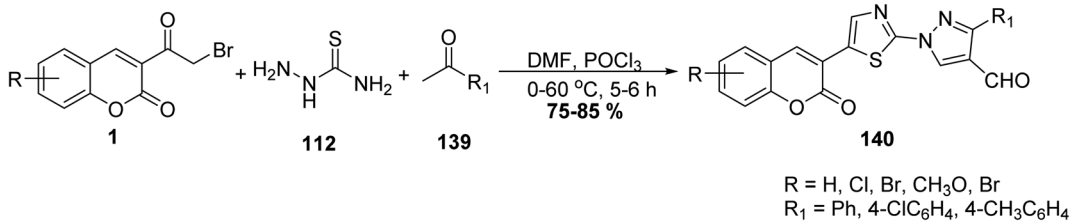
136i: $R_1 = R_2 = Br$, $R_3 = CH_3\text{-}C_6H_4$ **136j**: $R_1 = R_2 = Br$, $R_3 = C_6H_5$

136k: $R_1 = R_2 = H$, $R_3 = \beta$-naphthyl

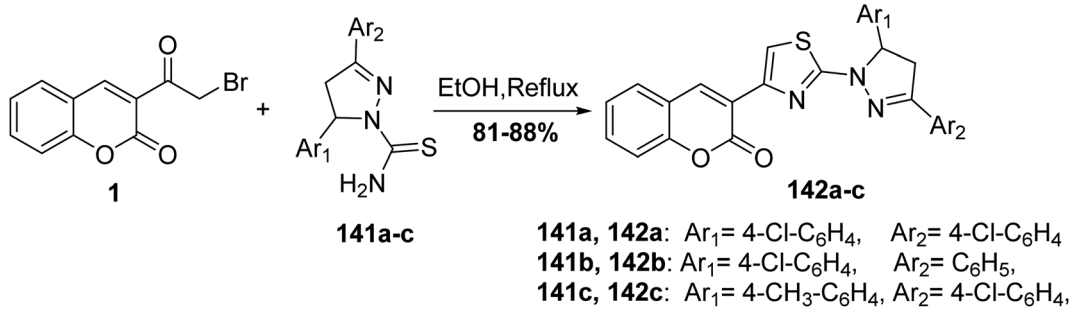
Scheme 57 Synthesis of 3-[2-(arylamino)thiazol-4-yl]coumarins **136a-k**.



Scheme 58 Multi-component synthesis of chromen-3-thiazol-2-arylacrylonitriles **138**.



Scheme 59 Vilsmeier–Haack reaction condition for the synthesis of products **140**.

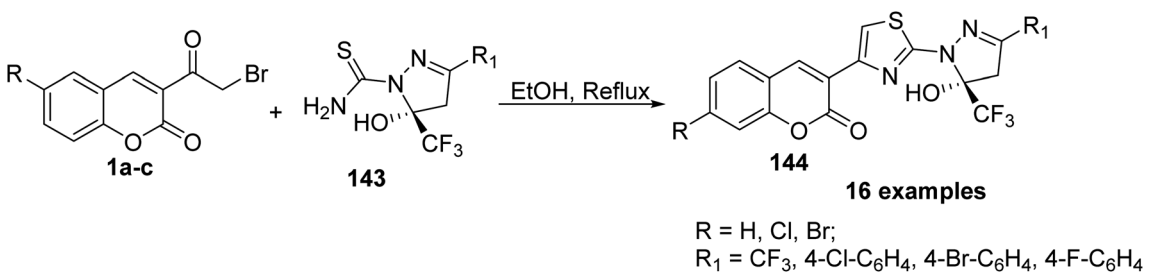


Scheme 60 Synthesis of 4,5-dihydropyrazolyl–thiazole–coumarin hybrids **142**.

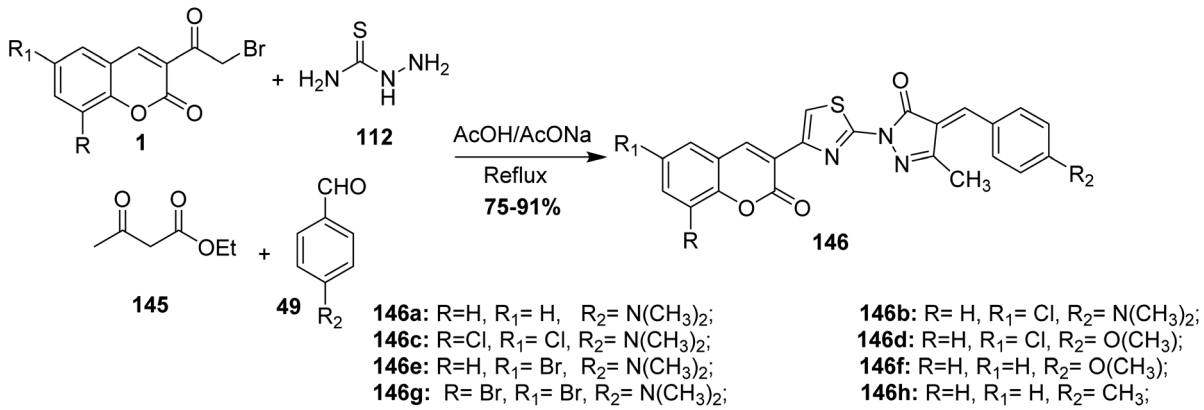
thiazolines **131** by the condensation of 3-(bromoacetyl) coumarin derivatives **1**, arylisothiocyanates **128**, and amine **130** (Scheme 54).[142]

A one-pot multi-component approach involving different substituted of 3-(bromoacetyl)coumarin derivatives **1**, phenyl isothiocyanates **128**, and *p*-phenylenediamine **132** in refluxing DMF have been carried out for getting the new series of bis (phenylimino dihydro thiazolyl-2*H*-chromene) **133** (Scheme 55).[143]

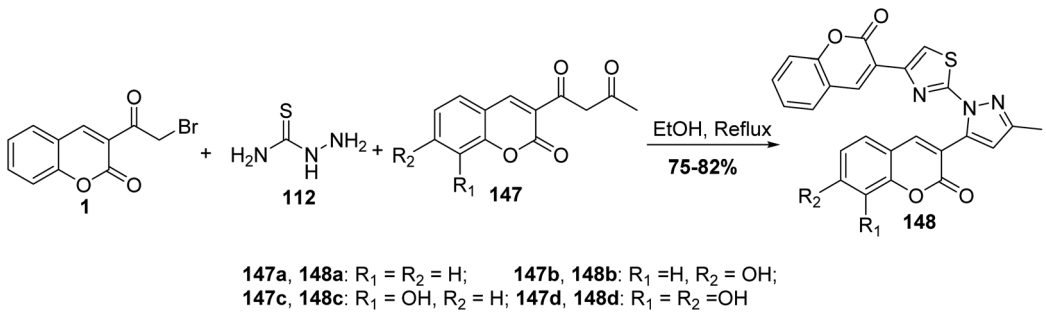
Microwave irradiation was reported as a green chemistry method for the synthesis of coumarin-3-yl-thiazol-3-yl-1,2,4-



Scheme 61 Synthesis annulated 4-(coumarin-3-yl)thiazoles **144**.



Scheme 62 Synthesis of coumarin bearing thiazol-pyrazolone moieties **146**.



Scheme 63 Coumarin bearing pyrazole and thiazole hybrids **148**.

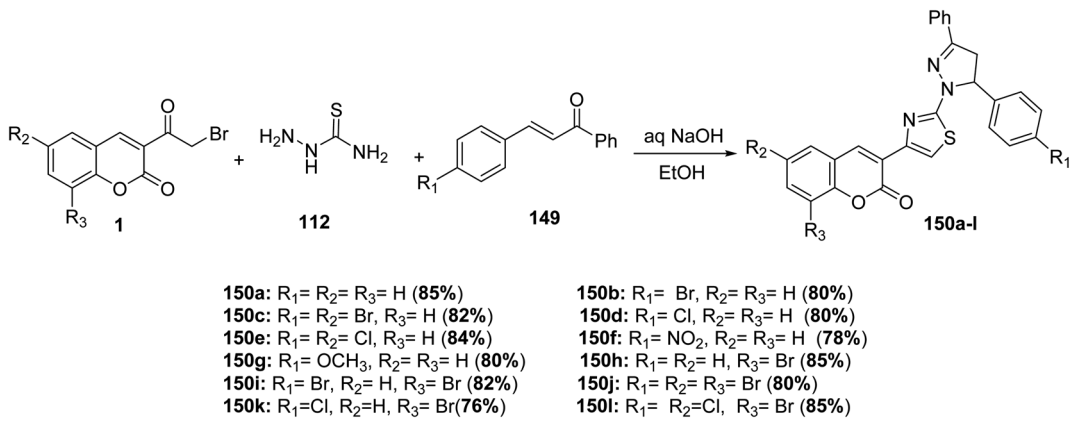
triazolin-3-ones **135** by Shaikh *et al.*[144] *via* mixing of 3-(bromoacetyl)coumarin derivatives **1,** 1,2,4-triazolone, **134** and aryl isothiocyanate **128** in DMF without using a catalyst (Scheme 56).

An efficient synthesis of 3-[2-(arylamino)thiazol-4-yl] coumarins **136a-k** *via* grinding of 3-(bromoacetyl)coumarin derivatives **1,** arylamines, **13** and potassium thiocyanate **20** in the least amount of ethanol as solvent under free catalyst and neat condition (Scheme 57).[109]

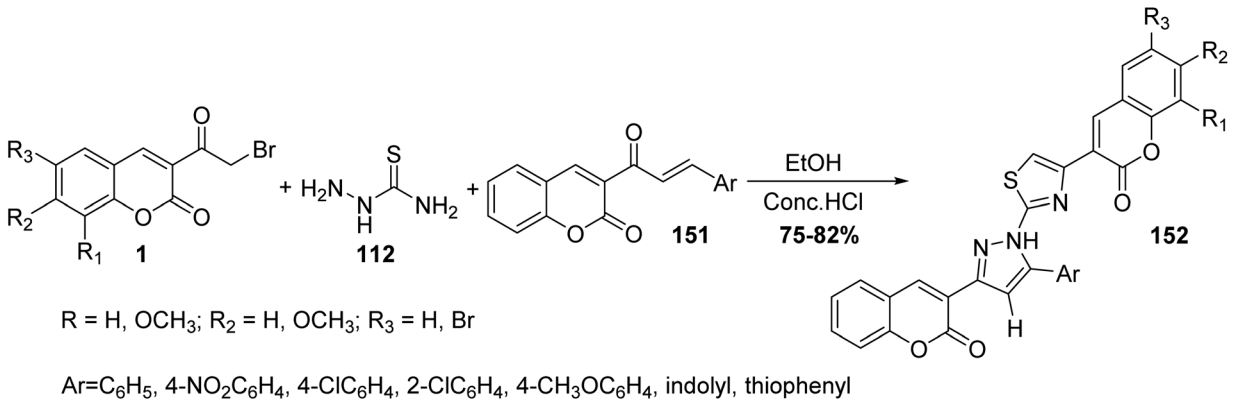
L-Proline catalyzed efficient one-pot three-component route for the synthesis of (2-oxo-2*H*-chromen-3-yl-thiazol-2-yl)-3-arylacrylonitriles **138a-h** *via* treating 3-(bromoacetyl)coumarin **1** with numerous aryl/heteryl aldehydes **49** and 2-cyanothioacetamide **137** (Scheme 58).[145]

5.10.3.5. Thiazolopyrazolones. A mixture of 3-(bromoacetyl) coumarin derivatives **1,** acetophenones **139,** and thiosemicarbazide **112** were subjected to a one-pot multicomponent Vilsmeier–Haack reaction condition afforded series of substituted thiazolyl-3-aryl-pyrazole-4-carbaldehydes bearing coumarin moiety **140** in moderate yields (Scheme 59).[146]

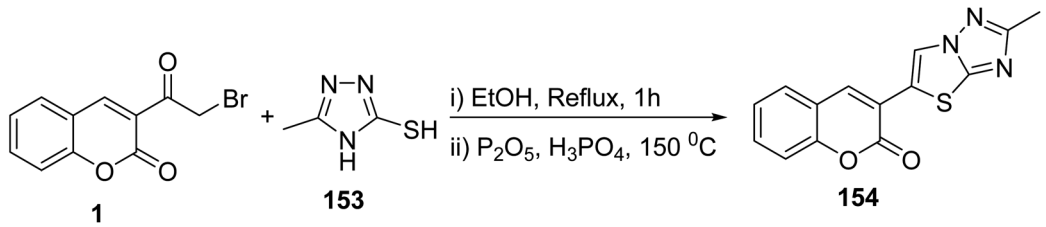
4,5-Dihydropyrazolyl–thiazole–coumarin systems **142** were obtained *via* the reaction of 3-(bromoacetyl)coumarin **1** and 3,5-



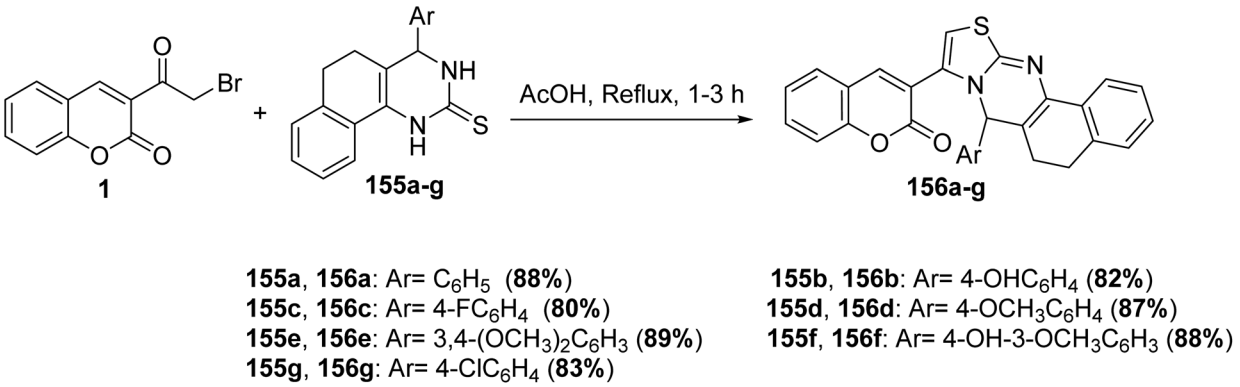
Scheme 64 Synthesis of binary pyrazol-1-thiazol-4-2*H*-chromen-2-one derivatives **150a-l**.



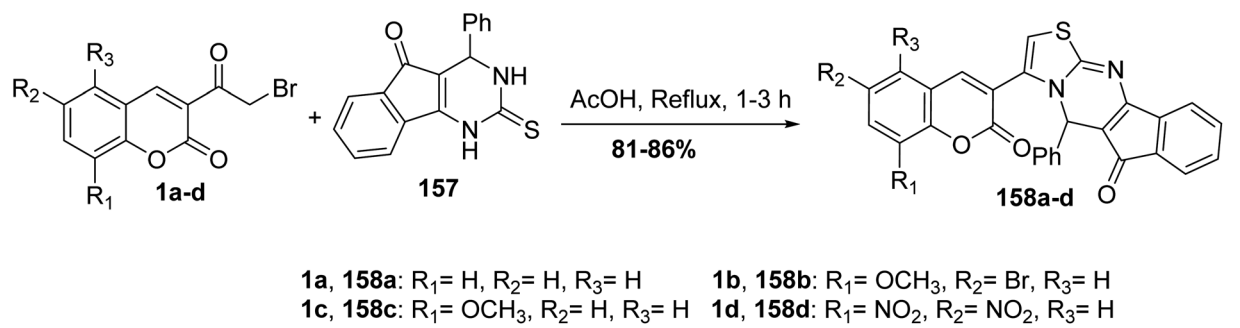
Scheme 65 Formation of (2*H*-chromen-5-phenyl-1*H*-pyrazol-thiazol-4-yl) chromenones **152**.



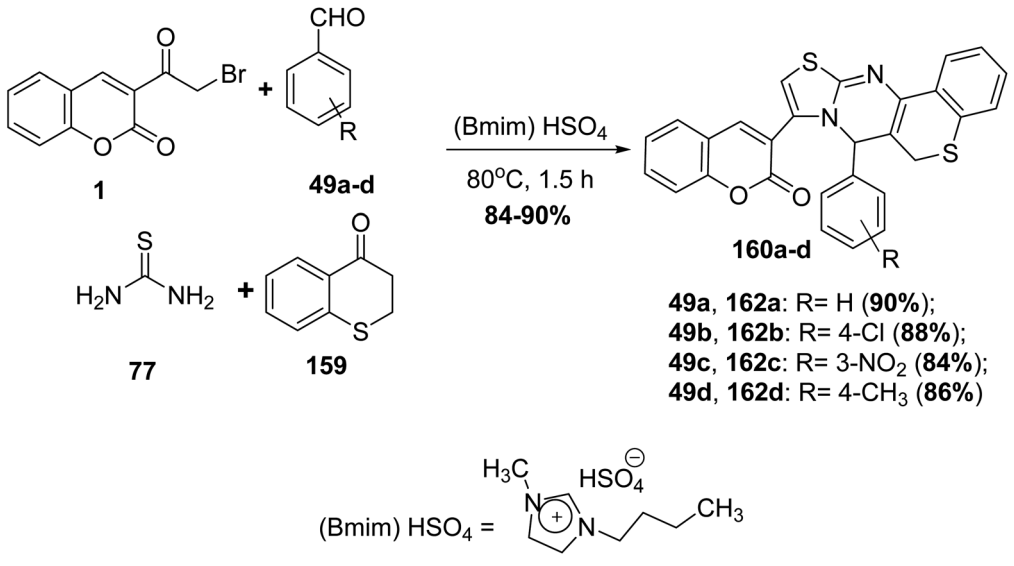
Scheme 66 Treatment of 3-(bromoacetyl)coumarin **1** with 5-phenyl-1,2,4-triazole-3-thiol **154**.



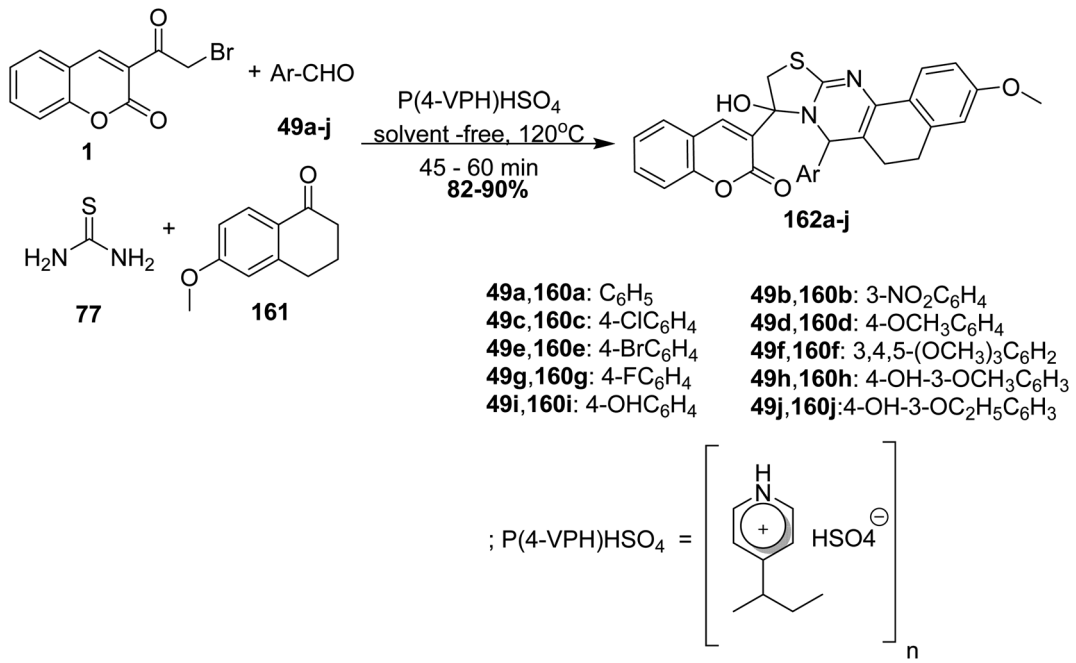
Scheme 67 Synthesis of fused thiazolo[3.2-*a*]pyrimidine derivatives **156**.



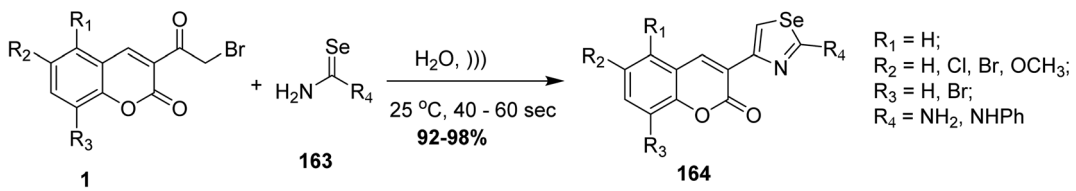
Scheme 68 Synthesis of phenylindeno[1,2-*d*]thiazolo[3,2-*a*]pyrimidin-6(5*H*)-ones **158**.



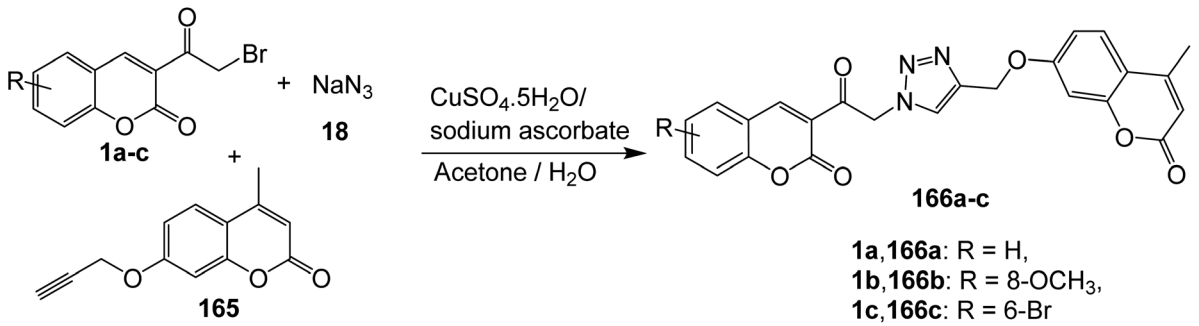
Scheme 69 One-pot four-component Biginelli reaction.



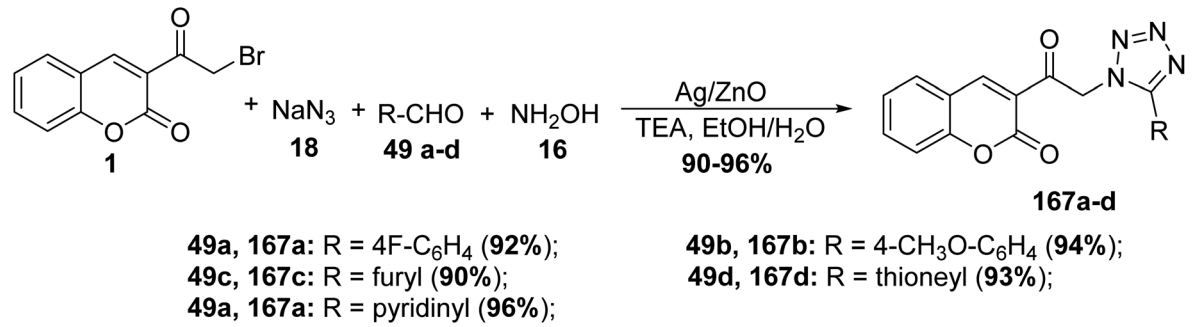
Scheme 70 Synthesis of fused thiazolo[2,3-*b*]quinazoline derivatives **162a-j**.



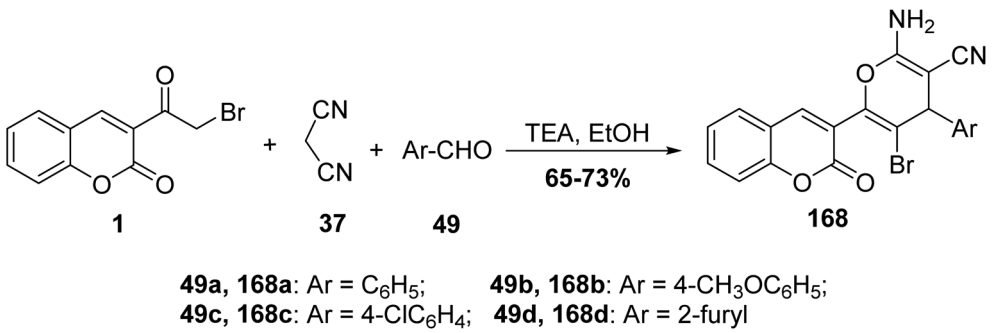
Scheme 71 Formation of 2,4-disubstituted selenazoles **164**.



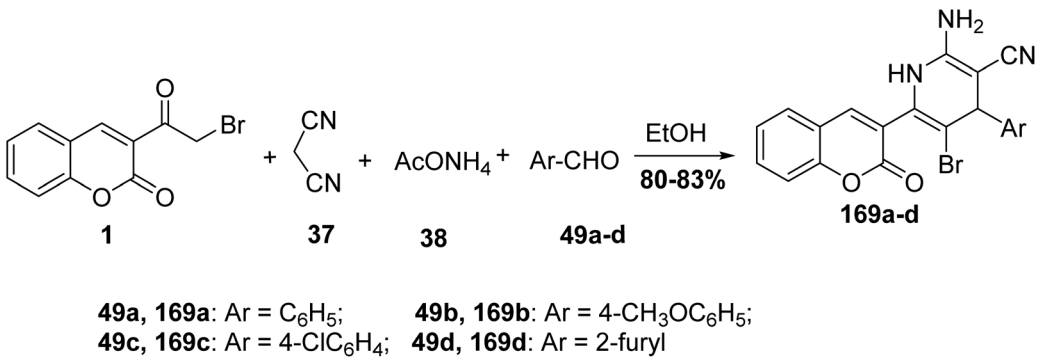
Scheme 72 Click cycloaddition reaction of 3-(bromoacetyl)coumarins **1a-c**.



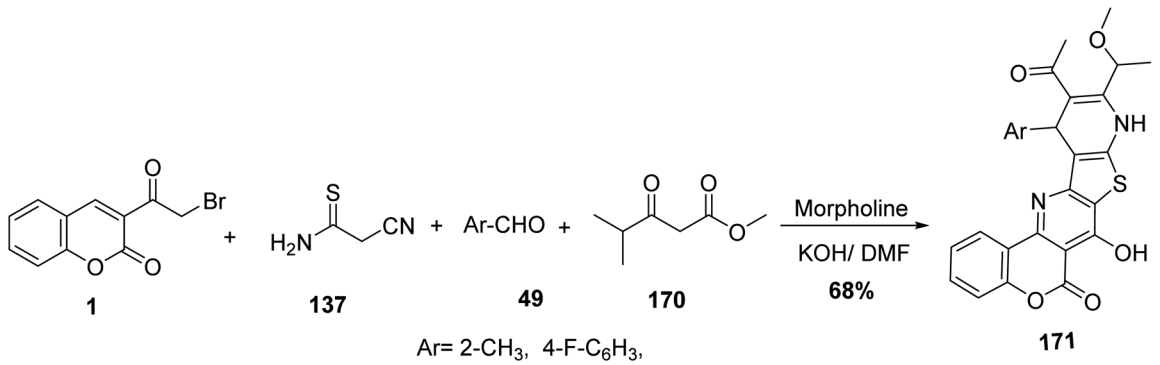
Scheme 73 Preparation of 1,5-disubstituted tetrazole **167**.



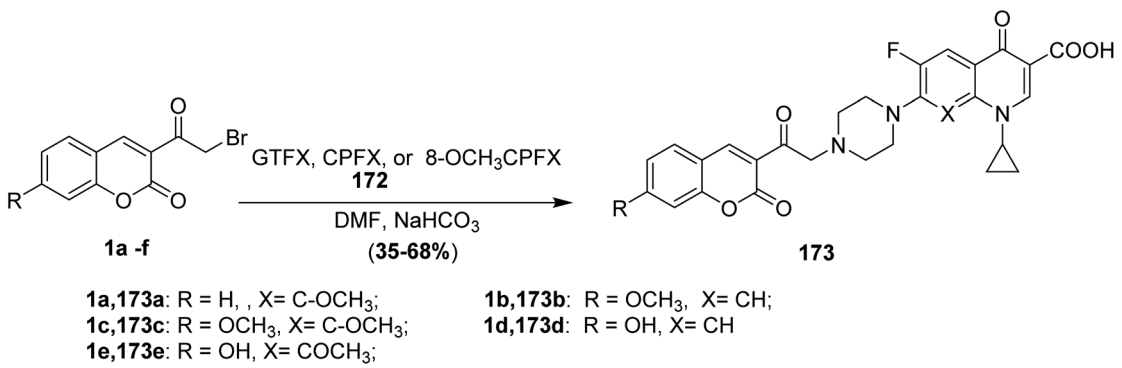
Scheme 74 Synthesis of 3-cyano-pyran derivatives **168**.



Scheme 75 Formation of pyridine derivatives **169a-d**.



Scheme 76 Synthesis of pyridines **171**.



Scheme 77 Formation of various fluoroquinolone derivatives **173**.

disubstituted phenyl-4,5-dihydropyrazole-1-carbothioamide **141** in ethanol (Scheme 60).[147]

5-Hydroxy-5-trifluoromethyl-4,5-dihydropyrazol-1-4-(coumarin-3-yl)thiazoles **144** were obtained by refluxing of 3-(bromoacetyl)coumarin derivatives **1** with 5-hydroxy-5-trifluoromethyl-4,5-dihydropyrazol-1-thiocarboxamides **143** in ethanol (Scheme 61).[148]

Synthesis of coumarin-substituted thiazolyl-pyrazolone derivatives **146** was reported by Pavurala *et al. via* a one-pot reaction of 3-(bromoacetyl)coumarin derivatives **1**, thiosemicarbazide **89**, aryl aldehyde **49**, and ethyl acetoacetate **145** in boiling acetic acid (Scheme 62).[149]

Series of pyrazoles bearing coumarin moieties **148** were prepared underwent Hantzsch cyclocondensation of 3-(bromoacetyl)coumarin **1**, thiosemicarbazide **112** and various 3-(acetoacetyl) coumarins **147** in refluxing ethanol (Scheme 63).[150]

One pot, three-component reaction of chalcones **149**, thiosemicarbazide **112**, and different substituted 3-(bromoacetyl) coumarin derivatives **1** in refluxing ethanol containing catalytic amount of aqueous sodium hydroxide was achieved as an effective route for the synthesis of 4,5-dihydro-3,5-diphenylpyrazol-1-thiazol-4-2*H*-chromen-2-one derivatives **150a-l** in one step (Scheme 64).[149]

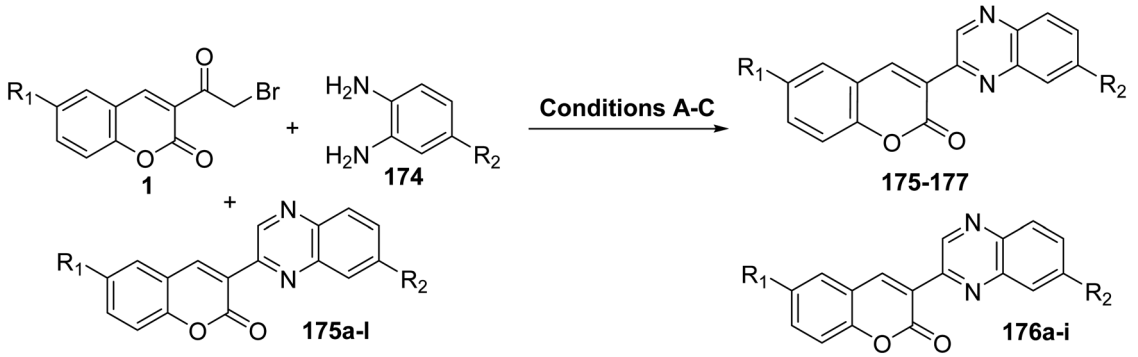
In the same fashion, Ghodsi *et al.* have been reported the synthesis of fused substituted thiazolyl-pyrazole-biscoumarin **152** through cyclocondensation of different coumarin chalcones **151**, thiosemicarbazide **112**, and 3-(bromoacetyl) coumarin derivatives **1** in ethanol in the presence of hydrochloric acid (Scheme 65).[151]

5.10.3.6. Thiazolotriazoles. On the other hand, the reaction of 3-(bromoacetyl)coumarin **1** with 5-phenyl-4*H*-1,2,4-triazole-3-thiol **153** gave fused thiazolo[3,2-*b*][1,2,4]triazol-5-chromenone **154** (Scheme 66).[152]

5.10.3.7. Thiazolopyrimidines. Novel fused thiazolo[3,2-*a*] pyrimidines **156a-g** have been obtained in good yields by treatment of 3-(bromoacetyl)coumarin **1** with aryl-3,4-dihydropyrimidin-2(1*H*)-thiones **155a-g** under conventional heating in acetic acid as solvent (Scheme 67).[153,154]

The cyclocondensation reaction of 3-(bromoacetyl)coumarin derivatives **1** with 4-phenyl-2-thioxo-indeno[1,2-*d*]pyrimidinone **157** in boiling acetic acid furnished phenylindeno[1,2-*d*]thiazolo[3,2-*a*]pyrimidin-6(5*H*)-ones **158** in high yields (Scheme 68).[155]

A new version of the Biginelli reaction using new variants was applied for the synthesis of substituted thiazolo[3,2-*a*]thiochromeno[4,3-*d*]pyrimidine **160a-d** through mixing an equimolar ratio of 3-(bromoacetyl)coumarin **1**, thiochromanone **159**, substituted benzaldehyde **49a-d** and thiourea **77** in one-pot reaction in the presence of $[Bmim]HSO_4$ as a mediated ionic liquid catalyst, leading to the formation of a double electrophilic pyrimidine-2(5*H*)-thione as an intermediate which cyclized directly to furnish the targeting products **160a-d** (Scheme 69).[157]

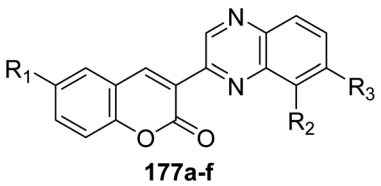


Condition A: PEG-600/100 °C, 30-60 min [161]

175a: R_1 =H, R_2 =H; **175b**: R_1= H, R_2 =CH_3;
175c: R_1 = H, R_2 = OCH_3; **175d**: R_1= H, R_2=NO_2;
175e: R_1= H, R_2=F; **175f**: R_1= H, R_2=Cl;
175g: R_1=NO_2, R_2=H; **175h**: R_1= NO_2, R_2= CH_3;
175i: R_1=NO_2, R_2 = OCH_3; **175j**: R_1= NO_2, R_2=NO_2;
175k: R_1=NO_2, R_2= F; **175l**: R_1= NO_2, R_2=Cl

Condition B: THD/Pyridine, RT, stirr [162]

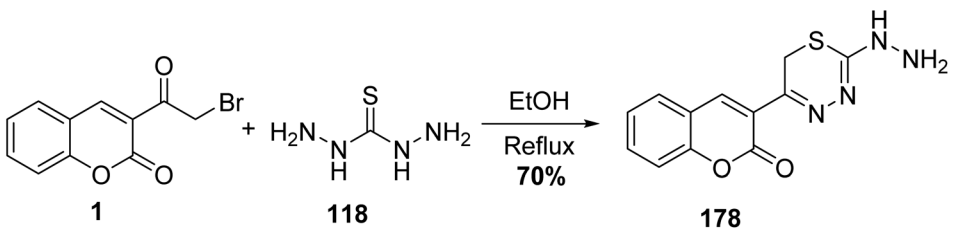
176a; R_1 = H, R_2 =Br, **176b**; R_1 =H, R_2 = Cl,
176c; R_1 = H, R_2 = CH_3, **176d**; R_1 =H. R_2 = H,
176e; R_1 =H, R_2 = Cl, **176f**; R_1 =H, R_2= CH_3,
176g; R_1 = Br, R_2 = H, **176h**; R_1 =Br, R_2 = Cl,
176i; R_1 =Br, R_2 = CH_3



Condition C: MW, 100 - 120 °C, 8 min [163]

177a: R_1 = H, R_2 = R_3 =H, **57%**;
177b: R_1 = H,R_2 = H, R_3 = CH_3; **92%**
177c: R_1 = H, R_2 = R_3 =CH_3; **95%**
177d: R_1 = H, R_2= H, R_3 = Br; **84%**
177e: R_1 = H, R_2 = R_3 = NO_2; **94%**
177f: R_1 = NO_2, , R_2 = R_3 =CH_3; **40%**

Scheme 78 Synthesis of 3-(quinoxalin-2-yl)-2*H*-chromen-2-ones **175–177**.



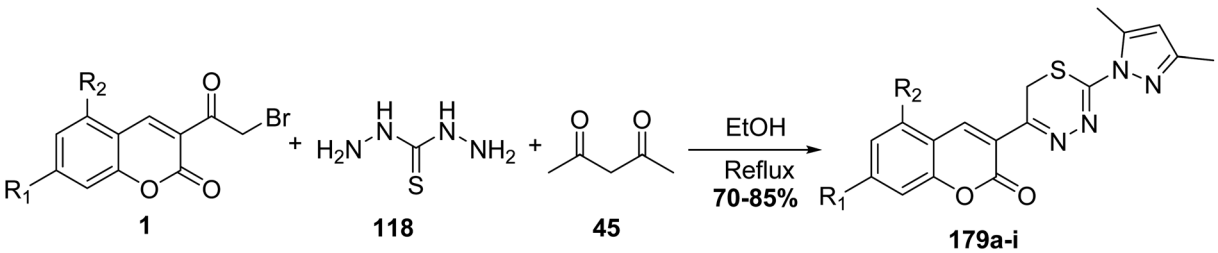
Scheme 79 Formation of 3-(2-hydrazino-6*H*-[1,3,4]thiadiazin-5-yl)-chromen-2-one **178**.

5.10.3.8. Thiazoloquinazolines. Biginelli reaction of 3-(bromoacetyl)coumarin **1,** aryl aldehyde **49a-j,** thiourea 77 and 6-methoxy-1-tetralone **161** in the presence of in poly(4-vinylpyridinium)hydrogen sulfate [P(4-VPH)HSO_4] as Brønsted acid catalyst under neat condition afforded aryl-thiazolo[2,3-*b*] quinazoline derivatives **162a-j** (Scheme 70).[156]

5.10.3.9. Selenazoles. An efficient synthesis of functionalized selenazoles **164** was achieved *via* ultrasonic irradiation of 3-(bromoacetyl)coumarin **1** with selenourea **163** at ambient temperature an aqueous medium under ultrasonic irradiation (Scheme 71).[99]

5.10.4. Synthesis of five-membered rings with three heteroatoms

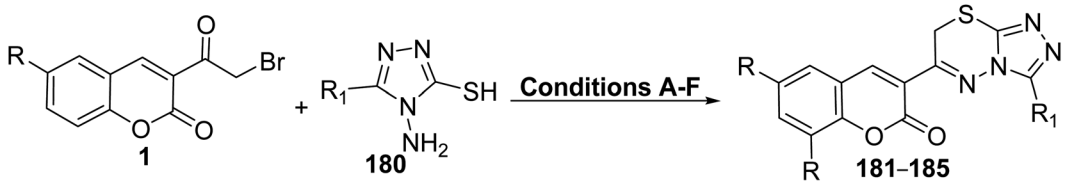
5.10.4.1. Triazoles. Cu(I)-catalyzed Huisgen 1,3-dipolar cycloaddition reaction of 3-(bromoacetyl)coumarin derivatives **1,** sodium azide **18,** and coumarin propargyl ethers **165** has been employed for the construction of bis-coumarinyl triazoles **166** (Scheme 72).[158]



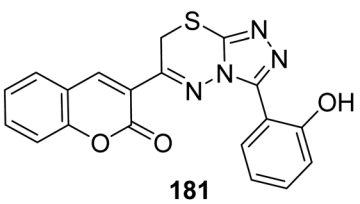
1 118 45 179a-i

179a: R_1= H, R_2= H;
179b: R_1= Br, R_2= H;
179c: R_1= H, R_2= OCH_3;
179d: R_1= Cl, R_2= Cl;
179e: R_1=$N(C_2H_5)_2$, R_2= H;
179f: R_1= Br, R_2= Br;
179g: R_1, R_2= 5,6-benzo,
179h: R_1= NO_2, R_2= H;
179i: R_1= Cl, R_2= H;

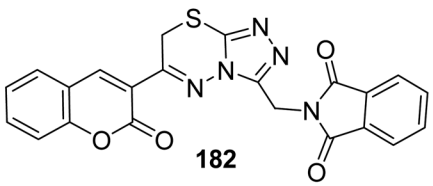
Scheme 80 Synthesis of pyrazolyl-thiadiazinyl-2*H*-chromenone derivatives **179a–i**.



1 180 181–185



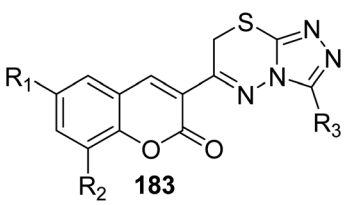
181



182

Condition A: AcOH/ EtOH, Reflux, 2h [166]

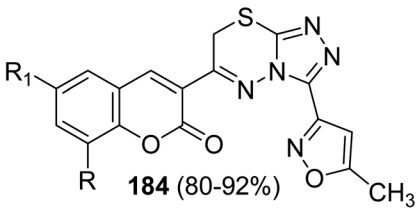
Condition B: EtOH, Et_3N, Reflux [167]



183

Condition C: EtOH, Reflux [168]

183a: R_1, R_2 = H ; R_3 = C_2H_4SH, **82%**
183b: R_1, = H ; R_2 = OCH_3 ; R_3 = C_2H_4SH, **80%**
183c: R_1, = Br ; R_2 = H ; R_3 = C_2H_4SH, **90%**
183d: R_1, R_2 = Br ; R_3 = C_2H_4SH, **92%**
183e: R_1, R_2 = H, R_3= $CH_2CH(CH_3)SH$ **86%**
183f: R_1, = H ; R_2 = OMe ; R_3= $CH_2CH(CH_3)SH$ **85%**
183g: R_1, = Br ; R_2 = H ; R_3 = R_3= $CH_2CH(CH_3)SH$ **89%**
183h: R_1, R_2 = Br, R_3= $CH_2CH(CH_3)SH$ **92%**

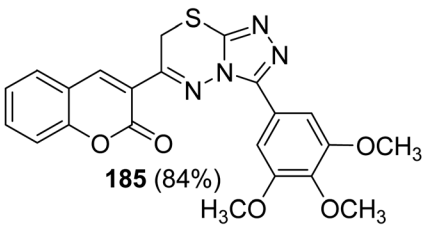


184 (80-92%)

Condition E: EtOH, Reflux [169]

R= H, Br, Cl,OCH_3, NO_2, $C(CH_3)_3$

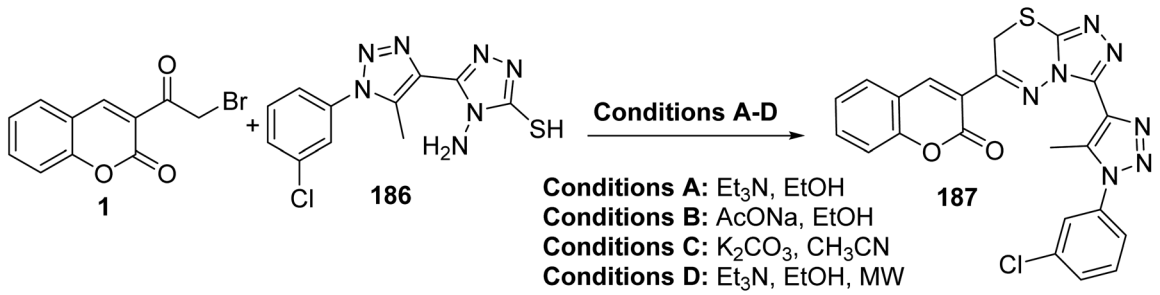
R_1= H, Br, Cl, OCH_3, NO_2, $C(CH_3)_3$



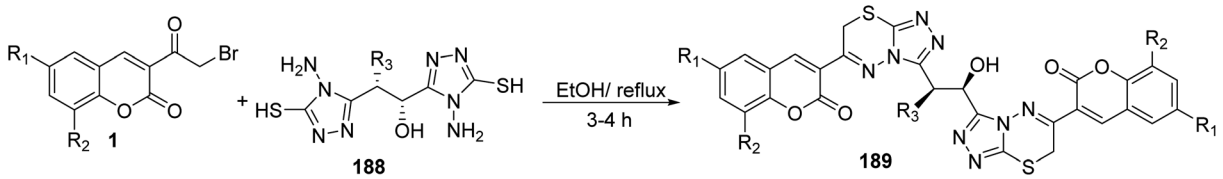
185 (84%)

Condition F: EtOH/ Reflux [47]

Scheme 81 Synthesis of coumarin[1,2,4]triazolo[3,4-*b*][1,3,4]thiadiazine hybrids **181–185**.



Scheme 82 Formation of triazolo[3,4-*b*]thiadiazines **187**.



189a: R_1=H, R_2= H, R_3= OH, **85%**
189b: R_1=Cl, R_2= H, R_3= OH, **84%**
189c: R_1=H, R_2= OCH_3, R_3= OH, **78%**
189d: R_1=Br, R_2= H, R_3= OH, **80%**
189e: R_1=Br, R_2= Br, R_3= OH, **85%**
189f: R_1=H, R_2= H, R_3= H, **84%**
189g: R_1=Cl, R_2= H, R_3= H, **80%**
189h: R_1=H, R_2= OCH_3, R_3= H, **75%**
189i: R_1=Br, R_2= H, R_3= H, **72%**
189j: R_1=Br, R_2= Br, R_3= H, **80%**

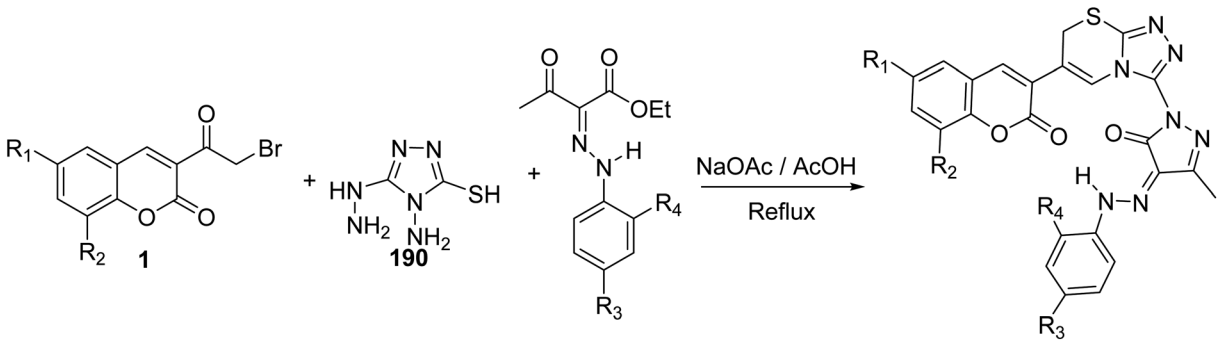
Scheme 83 Synthesis of bis coumarinyl bis triazolothiadiazinyl ethane derivatives **189**.

5.10.5. Synthesis of five-membered rings with four heteroatoms

5.10.5.1. Tetrazoles. 1,5-Disubstituted tetrazole based chromone derivatives **167a-d** were synthesized employing four-component condensation of 3-(bromoacetyl)coumarin **1**, aldehyde derivatives **49a-d**, sodium azide **18**, and hydroxylamine **16** in ethanol containing catalytic drops of trimethylamine, the reaction was supported by nanorods of zinc oxide (NRs) and Ag-doped ZnO nanocomposites (NCs) as photocatalysts (Scheme 73).[159]

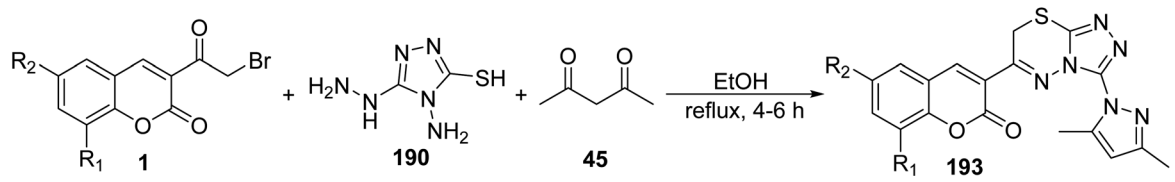
5.10.6. Synthesis of six-membered rings with one heteroatom

5.10.6.1. Pyran derivatives. Mohareb and MegallyAbdo[70] described the preparation of 2-amino-3-cyano-pyran derivatives



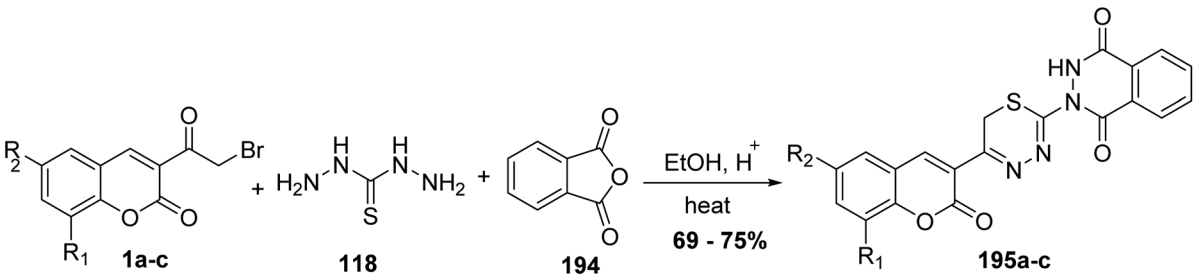
192a:R_1=R_2=R_4=H, R_3= CH_3, **89%**
192b: R_1=R_2=R_4=H, R_3=Cl, **85%**
192c:R_1=R_2=R_4=H, R_3=NO_2, , **84%**
192d:R_1=R_2=R_3= R_4=H, **88%**
192e:R_1=R_2=H, R_3=Cl, R_4=NO_2, **84%**
192f: R_1=R_3= R_4=H, R_2=OCH_3, **76%**
192g:R_1=R_4=H, R_2=OCH_3, R_3=NO_2, **80%**
192h: R_1=Br, R_2= H, R_3=NO_2, R_4=H; **86%**

Scheme 84 Synthesis of triazolothiadiazinyl-pyrazolone **192a-h**.



1a,193a:R_1=R_2=H, **90%**
1b,193b:R_1=$N(C_2H_5)_2$, R_2=H, **85** %
1c,193c:R_2=H, R_1=OCH_3, **85%**
1d,193d:R_1= 5,6-Benzo, R_2=H, **80%**
1e,193e:R_1=H, R_2=Cl, **84%**
1f,193f:R_1=R_2=Br, **83%**
1g,193g:R_1=H, R_2=Br, **82%**
1h,193h:R_1=R_2=Cl, **82%**
1i,193i: R_2=H, R_1=NO_2, **80%**

Scheme 85 One-pot synthesis of series of fused pyrazolyl triazolo thiadiazinyl chromenones **193**.



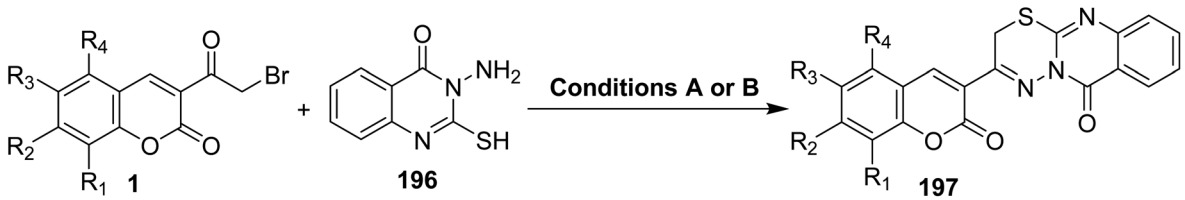
1a,**195a**: R_1 = R_2 =H;
1b,**195b**: R_1 =H, R_2 =Cl;
1c,**195c**: R_1 = R_2 =Br

Scheme 86 Multi-component reaction for the synthesis of thiadiazinyl-phthalazine-1,4-diones **195**.

168 using three-component reactions of 3-(bromoacetyl) coumarin **1** with malononitrile **37** and aromatic aldehydes **49** in boiling ethanol containing catalytic drops of trimethylamine (Scheme 74).

5.10.6.2. Pyridines. On the other hand, repeating the previous reaction using a catalytic amount of ammonium acetate **38** *in lieu* of triethylamine afforded the pyridine systems **169a-d** (Scheme 75).[70]

Multicomponent condensation of 3-(bromoacetyl)coumarin **1**, cyanothioacetamide **137**, benzaldehyde derivatives **49** and methyl 4-methyl-3-oxopentanoate **170** led to formation of fused chromeno[3″,4″:5′,6′]pyrido[2′,3′:4,5]thieno[3,2-e]pyridine derivatives **171** (Scheme 76).[160]



Condition A: K_2CO_3, MW/400 W, 4-6 min, **72-90%**
Condition B: EtOH, K_2CO_3 , reflux, 4-6 h, **66-82%**

1a,**197a**: R_1= H, R_2= H, R_3= H, R_4= H
1b,**197b**: R_1= H, R_2= H, R_3= Br, R_4= H
1c,**197c**: R_1= Br, R_2= H, R_3= Br, R_4= H
1d,**197d**: R_1= H, R_2= H, R_3= NO_2, R_4= H
1e,**197e**: R_1= NO_2, R_2= H, R_3= NO_2, R_4= H
1f,**197f**: R_1= H, R_2= H, R_3= Cl, R_4= H

Scheme 87 Synthesis of chromenothiadiazino[2,3-*b*]quinazolin-6-ones **197**.

Table 1 Examples of a vast array of biologically active molecules towards some diseases

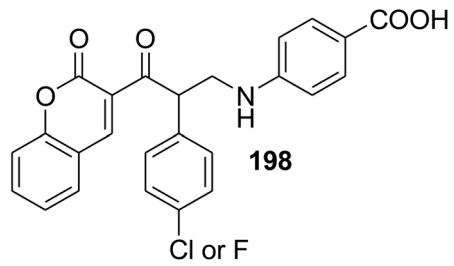
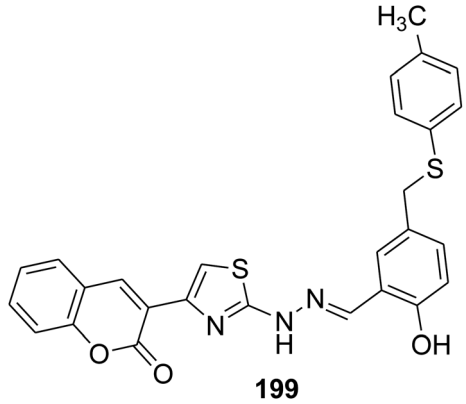
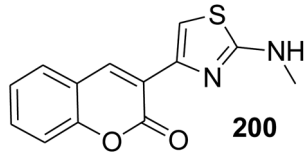
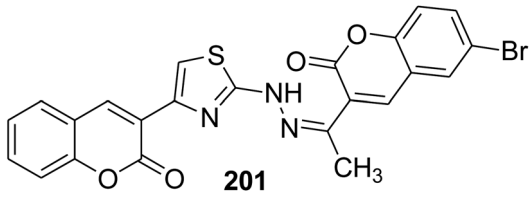
Structures	Activities	Ref.
 **198**	Antibacterial activity against: (*E. coli*, *S. aureus* and *P. aeruginosa*) Antifungal activity against: (*A. flavus*, *C. keratinophilum*, and *C. albicans*) Antioxidant activity: (moderate potency in scavenging DPPH radical (approximately 65%)	175
 **199**	Antibacterial activity (zone of inhibition, ZI) against: *S. aureus*, ZI = 36.8 ± 0.6 mm • *S. mutans*, ZI = 25.4 ± 0.5 mm • *K. pneumoniae*, ZI = 27.2 ± 0.5 mm • *E. coli*, ZI = 26.3 ± 0.5 mm	176
 **200**	Anti-influenza A virus H1N1: IC_{50} = 4.84 μg mL^{-1} in MDCK cells	108
 **201**	Antimicrobial agents: *M. tuberculosis* (MIC = 15 μM)	177

Table 1 (*Contd.*)

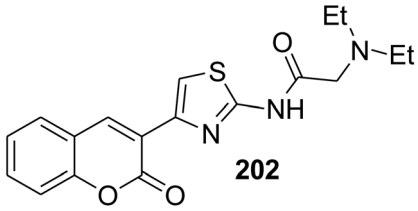
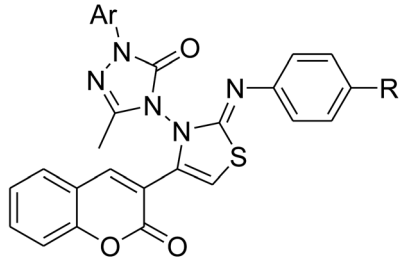
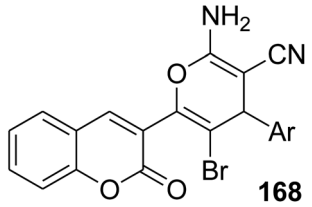
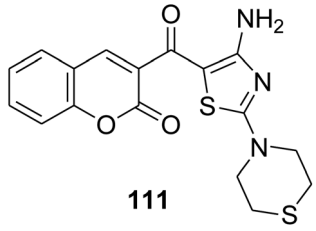
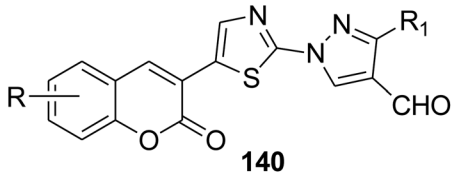
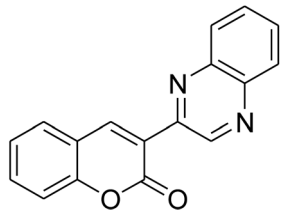
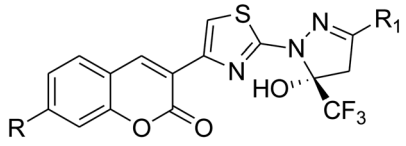
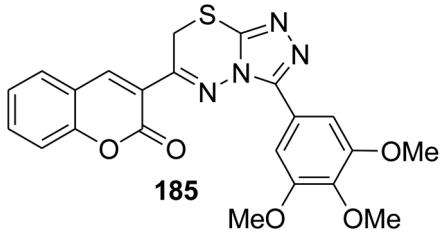
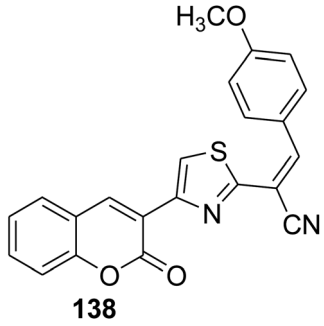
Structures	Activities	Ref.
 **202**	Anti-Alzheimeractivity: anti-cholinesterases (IC_{50} = 43 nM)	178
 **135** **Ar** = Ph, 4-$CH_3OC_6H_4$, 4-ClC_6H_4, 4-MeC_6H_4, 4-BrC_6H_4 **R** = H, 4-CH_3O, 4-Br, 4-CH_3	Anticancer activity against • Breast cancer • Lung cancer • Leukemia • Human cervical cancer	144
 **168**	Anticancer activity against human gastric cancer NUGC • 168a: Ar = 2-furyl, IC_{50} = 29 nM (against human gastric cancer NUGC) • 168b: Ar = 4-Cl-C_6H_5, IC_{50} = 89 nM (against MCF)	70
 **111**	Anticancer activity (against MCF-7, HepG2 and SW480 cells): IC_{50} = 7.5–16.9 μg mL^{-1}	132

Table 1 (*Contd.*)

Structures	Activities	Ref.
 **140**	Anticancer activity (against Hela cell line) • R = 6,8-diCl, R_1 = 4-MeC_6H_4, IC_{50} = 5.75 μM • R = 6,8-diBr, R_1 = 4-MeC_6H_4, IC_{50} = 6.25 μM	146
 **176**	Anticancer activity (against Melanoma tumor cell line): 55.75% GI	99
 **144**	Anti-inflammatory agents: 73–86% of inhibition after 1 h	148
R = H, Cl, Br; R_1 = CF_3, 4-Cl-C_6H_4, 4-Br-C_6H_4, 4-F-C_6H_4		
 **185**	Antiproliferative activity: IC_{50} = 10.364 ± 0.270 μM	170
 **138**	Anti-hepatocarcinoma activity: IC_{50} = 2.33 ± 0.004 μM	145

5.10.7. Synthesis of six-membered rings with two heteroatoms

5.10.7.1. Fluoroquinolone derivatives. Nucleophilic substitution reactions of fluoroquinolones **172** (GTFX, CPFX, and 8-OCH_3CPFX) with 3-(bromoacetyl)coumarin derivatives **1** in dimethylformamide, in the presence of $NaHCO_3$, provide fluoroquinolone derivatives **173** (Scheme 77).[62]

5.10.7.2. 3-(Quinoxalin-2-yl)-2H-chromen-2-ones. 3-(Quinoxalin-2-yl)-2*H*-chromen-2-ones **175-177** have been synthesized *via* substituted 3-(bromoacetyl)coumarins **1** and substituted *o*-phenylenediamines **174** in the presence of a catalyst such as PEG-600 or pyridine or without catalyst through microwave irradiation (Scheme 78).[161–163]

5.10.8. Synthesis of six-membered rings with three heteroatoms

5.10.8.1. Thiadiazin derivatives. One-pot condensation reaction between 3-(bromoacetyl)coumarin **1** and thiocarbohydrazide **118** as bishydrazide in ethanol and in the presence a catalytic amount of acetic acid afforded 2-hydrazino[1,3,4] thiadiazin-5-chromenone **178** (Scheme 79).[164]

5.10.8.2. Pyrazolyl-thiadiazine derivatives. Refluxing of an equimolar mixture of substituted 3-(bromoacetyl)coumarins **1**, acetylacetone **45**, and thiocarbohydrazide **118** in ethanol furnished pyrazolyl-thiadiazinyl-2*H*-chromenones **179a–i** (Scheme 80).[165]

5.10.8.3. Triazolo[3,4-b]thiadiazines. Series of functionalized 4-amino-4*H*-1,2,4-triazole-3-thiols **180** on reaction with substituted 3-(bromoacetyl)coumarins **1** under simple reaction conditions formed the title products coumarin-substituted [1,2,4]triazolo[3,4-*b*][1,3,4]thiadiazine hybrids **181–185** in good to excellent yields (Scheme 81).[47,166–169]

Triazolo[3,4-*b*]thiadiazine **187** was produced from the treatment of 3-(bromoacetyl)coumarin **1** with 4-aminotriazole-3-thiol **186** under both conventional and microwave conditions (Scheme 82).[170]

Bis coumarinyl bis triazolothiadiazinyl ethane derivatives **189** were synthesized through the reaction of ethane-1,2-diyl bis-4-amino-4*H*-1,2,4-triazole-3-thiols **188** with different substituted 3-(bromoacetyl)coumarin derivatives **1** in the presence of ethanol solvent (Scheme 83).[165]

A one-pot, multi-component reaction of 3-(bromoacetyl) coumarins **1**, 4-amino-5-hydrazino-4*H*-[1,2,4]triazole-3-thiol **190** and various ethyl 2-(2-(aryl)hydrazono)-3-oxobutanoate dervatives **191** in acetic acid in the presence of sodium acetate provide a direct route for the synthesis of corresponding triazolothiadiazinyl-pyrazolone **192a-h** (Scheme 84).[171]

Pavurala and Vedula[172] disclosed multi-component one-pot synthesis of pyrazolyl triazolo thiadiazinyl chromen-2–ones **193** was achieved *via* the multi-component reaction of 3-(bromoacetyl)coumarins **1**, 4-amino-5-hydrazino-4*H*-[1,2,4]triazole-3-thiol **190** and acetylacetone **45** in absolute ethanol (Scheme 85).

5.10.8.4. Thiadiazinyl-phthalazine-1,4-diones. Rao Chunduru and Rao[173] reported the synthesis of thiadiazinyl-phthalazine-1,4-dione derivatives **195** *via* one-pot condensation reaction of 3-(bromoacetyl)coumarins **1**, thiocarbohydrazide **118**, and phthalic anhydride **194** in ethanol containing a catalytic amount of acetic acid (Scheme 86).

5.10.8.5. Thiadiazino[2,3-b]quinazolin-6(2H)-ones. An efficient one-pot synthesis of chromenyl[1,3,4]thiadiazino[2,3-*b*] quinazolin-6(2*H*)-ones **197** in high yields through cyclocondensation of 3-(bromoacetyl)coumarins **1** with 3-amino-2mercapto-3*H*-quinazolin-4-one **196** under the conventional and microwave conditions in the presence of potassium carbonate (Scheme 87).[174]

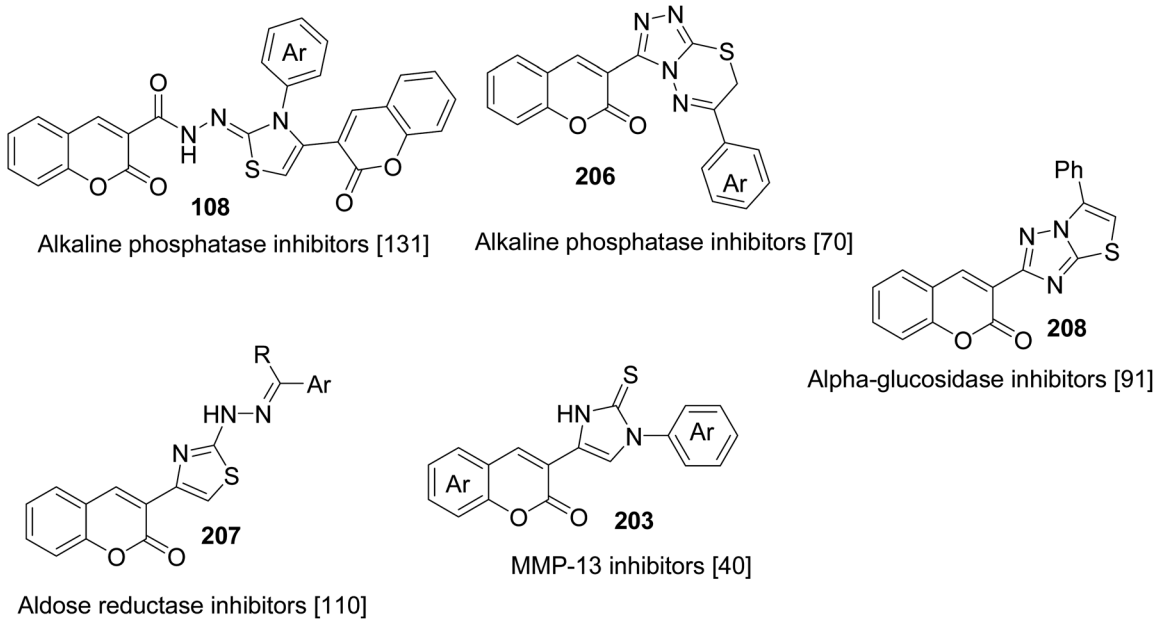
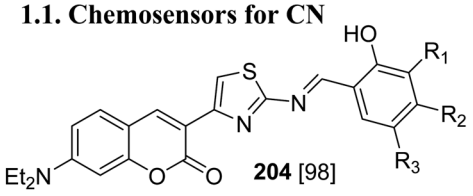


Fig. 6 Representative inhibitors of metalloproteinase with significant inhibitory effects.

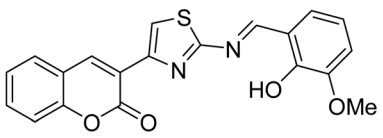
1. Fluorescent Chemosensors for Anions

1.1. Chemosensors for $CN^{\ominus}$



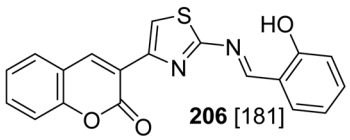
204 [98]

$R_1 = R_2 = R_3 = H$
$R_1 = OMe; R_2 = R_3 = H$
$R_1 = R_3 = H; R_2 = OMe$
$R_1 = R_2 = H; R_3 = Me$
$R_1 = R_2 = H; R_3 = Cl$



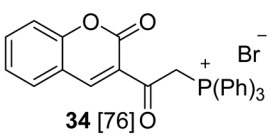
205 [102]

1.2. Chemosensors for $F^{\ominus}$

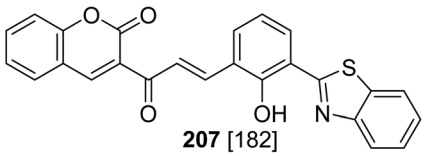


206 [181]

1.3. Chemosensors for $ClO^{\ominus}$



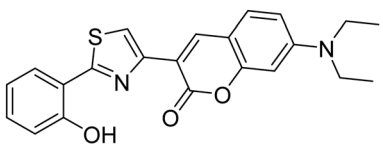
34 [76]



207 [182]

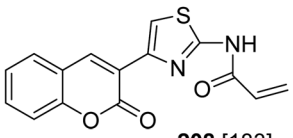
2. Fluorescent Chemosensors for Metal Ions

2.1. Chemosensors for Cu^{2+}/Cu^{+}



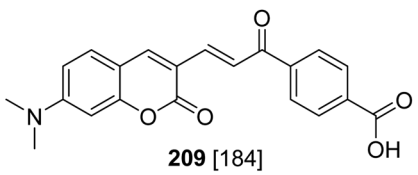
100 [96]

2.2. Chemosensors for Hg^{2+}



208 [183]

3. Fluorescent Chemosensors for Biological Thiols



209 [184]

Fig. 7 Fluorescent chemosensors towards metal cations, anions, and biomolecules.

6. Applications

6.1. Biological activities

3-(Bromoacetyl)coumarins are being employed as privileged building blocks for the production of several bioactive heterocyclic compounds with a broad spectrum of medicinal agents including antibacterial, antifungal, antioxidant, anticancer, anti-inflammatory, anti-hepatocarcinoma, and antiproliferative agents (Table 1). Moreover, many approaches have also been explored for the construction and synthesis of a diverse range of inhibitors of metalloproteinase with significant inhibitory effects. These as a versatile scaffold include, for example, alkaline phosphatase,[131] aldose reductase,[110] alpha-glucosidase,[91] and MMP-13 (ref. 40) inhibitors (Fig. 6).

6.2. Analytical applications

3-(Bromoacetyl)coumarin and 3-bromoacetyl-7-methoxycoumarin were used for the analysis of an emerging contaminant, perfluorinated substances.[179,180] 3-(Bromoacetyl) coumarins are versatile scaffolds with pivotal templates which have a vast array of applications in the field of fluorescent chemosensors towards metal cations, anions, and biomolecules[181–184] (Fig. 7).

7. Conclusion

This review has illuminated different aspects of 3-bromoacetylcoumarin **1** and its derivatives chemistry up to the beginning of 2021. It implies many sections on the synthesis of bromoacetylcoumarin derivatives. Besides different chemical reactions of bromoacetylcoumarins with various reagents, their biological evaluations and analytical application have been presented. Eventually, we hope that showcasing information accumulated over the years in developing 3-(bromoacetyl)coumarins core ranging from chemistry to applications will supplement the ongoing and forthcoming efforts towards the advancement of new functional molecular materials in the industry, biochemistry, and the environment.

Conflicts of interest

There are no conflicts to declare.

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