2-Methyl-4-Oxo-4*H*-1-benzopyran-4-one as a Synthon in Heterocyclic Chemistry

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I Introduction.

The title benzopyranone (trivial name: 2-methylchromone) **1** being an α,β-unsaturated ketone possesses two electron deficient carbon atoms, namely C-2 and C-4. It can also be regarded as an intramolecular enol ether of the diketone **2**. The methyl group at its 2-position being a part of vinylogous methyl ketone is also active. Because of these characteristics 2-methylchromone (**1**) undergoes various types of reactions. So it is regarded as a synthon of the compounds directly obtainable from it as well as from the derivatives prepared by simple halogenation, oxidation and methylenation of its active methyl group. The present review gives a comprehensive account of the synthesis and application of the title pyranone **1** reported up to 2004. In this review the 4-oxo-4*H*-1-benzopyran-2-yl moiety is abbreviated as 'Chr' so that 1-benzopyran-4-one having 'X' substitution at its 2-position is represented by ChrX. Alkyl, alkoxy and halogeno substitutents in and some heterocyclic moieties fused with the benzene ring remain unaffected in most of the reactions described for the unsubstituted 2-methylchromone (**1**) in this review.

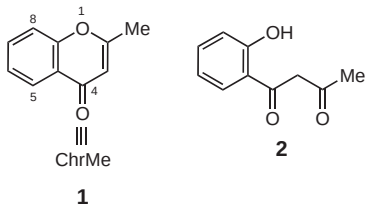


Figure 1

II Synthesis.

2-Methylchromone is generally prepared by acid catalysed cyclisation of ω-acetyl-2-hydroxyacetophenone **2** obtainable by Baker-Venkataraman rearrangement of 2-acetoxy-acetophenone **3** (R^1 = Ac, R^2 = Me) in the presence of alkali [1]. A better yield of **2** is obtained by treating the aforesaid acetophenone with NaH-DMSO at ambient temperature [2]. The most suitable method to prepare **2** is, however, acylation of 2-hydroxyaceto-phenone with ethyl acetate in the presence of molecular-ised sodium [1a,3] or sodium hydride [4]. A six-coordinated cobalt-Schiff base complex [5], refluxing ethanol containing morpholine [6], and irradiation in the presence of I_2 or Br_2 [7] also promote conversion of **2** to **1**. Preparation of the diketone **2** by acylating 2-hydroxy-acetophenone with ethyl acetate followed followed by its acid catalysed cyclisation is, however, still the method of choice for the synthesis of ChrMe.

Other reactions leading to the formation of ChrMe are also mentioned here. Heating 2-hydroxyacetophenone with acetic anhydride and anhydrous sodium acetate results in ChrMe in addition to 3-acetyl-2-methylchromone and 4-methylcoumarin [8]. A 2,4-dihydroxyacetophenone derivative on similar reaction gives mainly the corresponding 7-acetoxy-2-methylchromone derivative [8c,d]. Reaction of *t*-butyl lithioacetate with 2-hydroxy-acetophenone and subsequent acid hydrolysis of the resultant hemiacetal (2-hydroxy-2-methylchromanone) provide ChrMe in 85% overall yield [9]. The enol acetate of 2-acetoxy-acetophenone upon irradiation with UV light gives a mixture of **1** and 2-acetoxyacetophenone [10]. *p*-Cresyl β-chlorocrotonate on being treated with HF at 100 °C undergoes tandem Fries rearrangement and cyclisation to give 2,6-dimethylchromone [11]. ω-Acetyl-2-acetoxy-acetophenone, obtained by condensation of 2-acetoxy-benzoyl chloride with lithium enolate of acetone, affords **1** on heating with HCl-AcOH [12]. Cyclocondensation of methyl salicylate with dimethyl allene-1,3-dicarboxylate in the presence of *t*-BuOK in *t*-BuOH gives the disubstituted chromone **4** which on acid catalysed hydrolysis with concomitant decarboxylation leads to **1** [13]. The phosphorane **3** (R^1 = H, R^2 = $CH=PPh_3$), derived from 2-hydroxy (or acetoxy) phenacyl halide and PPh_3, gives **1** on acetylation with Ac_2O or AcCl [14,15]. The anilide **3** [R^1 = Ac, R^2 = $C(CONHPh)=PPh_3$], derived from the acid **3** (R^1 = Ac, R^2 = OH) and *N*-phenylketeniminylidene triphenyl-phosphorane ($Ph_3P=C=C=NPh$), on being heated under reflux in toluene – ethanol (95:5) elides phenyl isocyanate and the resultant acylphosphorane intermediate **3** (R^1 = Ac, R^2 = $CH=PPh_3$) gives **1** *via* intramolecular ester carbonyl olefination; the chromone **1** is always admixed with a little amount of the anilide **5** (X = CONHPh) arising from the intramolecular Wittig reaction of the substrate itself [16]. The aforesaid acyl phosphorane **3** (R^1 = Ac, R^2 = $CH=PPh_3$) has also been prepared by treating the ester **3** [R^1 = Ac, R^2 = OSi (*t*-Bu)Me_2] with $Me_3SiCH=PPh_3$ [17].

2-Methylchromones have also been obtained from some heterocyclic compounds. Dehydrogenation of 2-methyl-chromanones has been effected by $Pd(PPh_3)_2Cl_2$ or Pd(II) acetylacetonate [18], triphenylmethyl perchlorate [19] and DMSO-I_2 [20]. 2,2-Dimethylchromanone on treatment with thallium (III) nitrate in MeOH containing $HClO_4$ is

converted into **1** [21]. Irradiation of chromone in MeOH-HCl induces homolytic addition of MeOH to its 2,3-double bond, the resulting 2-hydroxymethylchromanone yielding **1** presumably by acid catalysed dehydration and hydrogen shift [22]. 3-Substituted chromone **6** (X = CO_2Me, SOC_6H_4Me-*p*) reacts with lithium dimethylcuprate to yield a stereoisomeric mixture of the chromanone **7** [23,24]. Treating **7** (X = CO_2Me) with NaCl in moist DMSO [23] and heating **7** (X = SOC_6H_4Me-*p*) at 140 ºC [24] produce ChrMe. Acid catalysed hydrolysis of 3-acetyl-4-hydroxycoumarin is followed by decarboxylation and recyclisation to ChrMe [25]. The isoxazole **8**, obtained by [3+2]cycloaddition between acetonitrile oxide and tributylethynylstannane, on cross coupling with 2-iodophenyl methoxymethyl ether in the presence of $Pd(PPh_3)_2Cl_2$ followed by hydrogenation over nickel in MeOH and subsequent treatment with HCl-AcOH gives ChrMe [26].

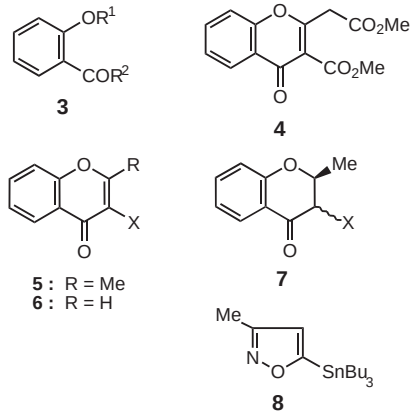


Figure 2

III Reaction at the Carbonyl Group.

Phosphorus pentasulfide converts **1** in benzene under reflux to 2-methylchromene-4-thione **9** (X = S) [27,28]; the latter on heating with selenium dioxide in dioxane undergoes oxidative desulfurisation to the former [28]. The chromone **9** (X = CH_2 or CPh_2), obtained by treating the thione **9** (X = S) with CH_2N_2 or Ph_2CN_2, gives ChrMe on warming with $SOCl_2$ [29]. The thione **9** (X = S) is derivatised by tosylhydrazine to **9** (X = NNHTs) and the carbene generated from the latter in MeOH-MeONa by photolysis gives the 2*H*-chromene **10** through the intermediacy of 2-methyl-1-benzopyrylium ion [30]. Regioselective reduction of **1** is still unknown. A solution of sodium borohydride and nickel chloride in MeOH brings about steroselective reduction of **1** to the chromanol **11** [31]. PhMgBr and Me_3CMgI undergo 1,2-addition to the carbonyl group of **1** in ether containing $HClO_4$ giving the pyrylium perchlorates **12** (R = Ph and CMe_3) [32]. Acetophenone-oxime reacts with **1** in the presence of lithium diisopropylamide to give the spiroisoxazole derivative **13** [33]. That the formation of **9** (X = NNHR, R = Ph or $CSNH_2$) may not involve the initial 1,2-addition of the nucleophile to the pyrone carbonyl is discussed in section VI.2.

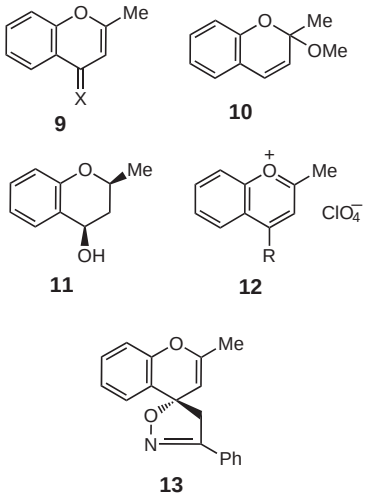
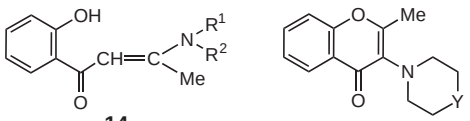


Figure 3

IV 3-Substituted 2-Methylchromone from 2-Methylchromone **1**.

Heating **1** and *N*-bromosuccinimide together in CCl_4 under reflux gives a mixture of $ChrCH_2Br$, 3-bromo-2-methylchromone **5** (X = Br) and 3,6,8-tribromo-2-methylchromone [34]. It is relevant to mention here that **2** on irradiation in Br_2-$CHCl_3$ gives **5** (X = Br) together with **1** [7]. SO_2Cl_2 reacts with **1** dissolved in CCl_4 to give **5** (X = Cl) [35], a better yield being obtained by carrying out the reaction in CH_2Cl_2 in the presence of K-10 clay [36]. NaOCl also converts **1** dissolved in AcOH-H_2O to **5** (X = Cl) [37]. 3-Bromochromone **5** (X = Br) can also be prepared by refluxing **1** with pyrrolidine in MeOH followed by treating the resultant enaminoketone **14** (R^1R^2 = $CH_2CH_2CH_2CH_2$) with a chloroform solution of bromine [38]. Chloromethylation of **1** with paraformaldehyde – HCl gas in AcOH as well as with $MeOCH_2Cl$ in the presence of fuming H_2SO_4 to **5** (X = CH_2Cl) is known [39]. The bromochromone **5** (X = Br) gives the nitrogen heterocycle **15** (Y = bond, CH_2, O, NMe) by treatment with the appropriate cyclic secondary amine [34]. Formation of other 3-substituted 2-methylchromones through initial addition to the olefinic bond of the pyrone **1** is discussed in the following section.

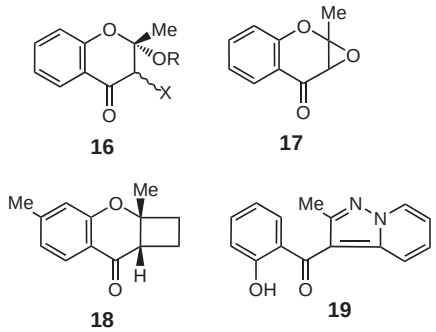


14 **15**

Figure 4

V Addition and Cycloaddition to the 2,3-Olefinic Bond.

UV light induced homolytic addition of MeOH to the 2,3-olefinic bond of **1** in MeOH-HCl [22] has been mentioned in section II. Electrolysis of **1** in a 0.1 molar solution of KX (X = Cl, Br) in 4:1 MeOH-H_2O at a graphite anode affords the unstable chromanone **16** (R = Me, X = Cl, Br) that decomposes to 3-halo-2-methyl-chromone slowly on keeping and rapidly on heating or treating with K_2CO_3 [40]. Expoxidation of **1** by alkaline H_2O_2 is always accompanied by base catalysed rearrangement to an appreciable extent of the resultant epoxide **17** to 3-hydroxy-2-methylchromone **5** (X = OH) presumably *via* the diol **16** (R = H, X = OH) [41]. The epoxide **17** rearranges to **5** (X = OH) with *p*-toluenesulfonic acid (PTSA) as well as trichloroacetic acid in benzene but gives **16** (R = Et, X = β-OH) with PTSA in ethanol [41]. Irradiation of a benzene solution of 2,7-dimethylchromone with a continuous flow of ethylene furnishes the [2+2]cycloadduct **18** [42]. [3+2]Cycloaddition between **1** and the ylid generated from *N*-aminopyridinum iodide in DMF containing K_2CO_3 at ambient temperature is followed by pyran ring opening and oxidation to give the pyridopyrazole **19** [43].



16 **17**

18 **19**

Figure 5

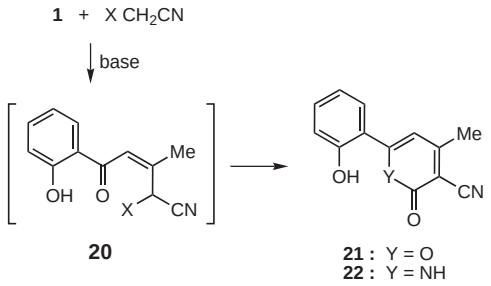
VI Conjugate Addition of Nucleophiles.

Conjugate additions of nucleophiles to the α,β-unsaturated carbonyl functionality of **1** are mostly followed by opening of the pyran ring; the resultant compounds depending on the nature of the nucleophiles may undergo further transformations.

VI.1 Conjugate Addition of Carbon Nucleophiles.

Reaction of **1** with lithium dimethylcuprate is not clean [44] but use of MeCu-BF_3 is effective in providing 2,2-dimethylchromanone in 76% yield [45]. Base catalysed Michael addition of ethyl cyanoacetate with concomitant opening of the pyran ring gives **20** (X = CO_2Et) that eventually cyclises to the lactone **21** [46]. Similar reaction of $CH_2(CN)_2$ with **1** gives **20** (X = CN) that on partial hydrolysis to the amide **20** (X = $CONH_2$) and cyclisation gives the pyridone **22**; the latter (**22**) is also obtained by reacting **1** with cyanoacetamide [46].

Scheme 1

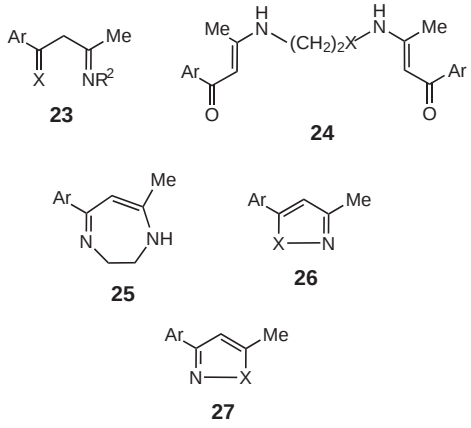


20

21 : Y = O
22 : Y = NH

VI.2 Conjugate Addition of Nitrogen Nucleophiles.

Conjugate addition of an alkylamine NHR^1R^2 (R^1 = H, R^2 = Me, Et, *n*-propyl, *n*-butyl, $PhCH_2$) to **1** is followed by opening of the pyran ring; the resultant enaminoketone **14** (R^1 = H) may remain in tautomeric equilibrium with the imine **23** (X = O) [47]. 2,6-Dimethyl-chromone gives similar type of compounds with the aforesaid alkylamine [48]. Reaction of **1** with ethylenediamine gives a mixture of **24** (X = bond) and **25** [49] whereas that with $NH_2(CH_2)_2XNH_2$ (X = $NHCH_2CH_2$) gives **24** [50]. Reactions of γ-pyrones including 2-methylchromone with hydrazines and hydroxylamine have been reviewed [51]. ChrMe reacts with NH_2XH (X = O, NH, NPh) in different media under conventional heating [47,52] as well as under microwave irradiation [52] to give **26**, which is also obtainable from **14** (R^1 = H, R^2 = alkyl) and NH_2XH [47]. The reported formation of **26** admixed with its isomer **27** (X = O) by the action of NH_2OH on **1** [53] warrants further scrutiny. Keeping **1** with phenyl-hydrazine for 20 days at room temperature gives the pyrazole **26** (X = NPh) whereas heating the mixture at 110 °C gives the hydrazone **9** (X = NNHPh), the latter being formed by sequential derivatisation of the carbonyl group of the initially formed 1,4-adduct and elimination of $PhNHNH_2$ [54]. A mixture of **1** and methylhydrazine in refluxing ethanol forms the pyrazoles **26** and **27** (X = NMe), the latter being the major product [55]. Depending on the reaction conditions the initial 1,4-adduct of **1** with thio-semicarbazide may give any of **9** (X = $NNHCSNH_2$), **23** (X = $NNHCSNH_2$, R^2 = $NHCSNH_2$) and **26** (X = NH) [56].



For **23-27 :** Ar = 2-hydroxyphenyl

Figure 6

VII Reactions Involving Active Methyl Group.

The reaction of 2,6-dimethylchromone with $SOCl_2$ in boiling benzene gives 6-methyl-2-trichloromethyl chromone [48]. Conversion of **1** by *N*-bromosuccinimide to 2-bromomethylchromone (**28**) and other bromo substituted 2-methylchromones [34] has been mentioned in section IV. Bromination of **1** with slightly more than two equivalents of bromine in refluxing benzene is likely to form the dibromo compound **29** [57]. ChrMe forms the pyridinium salt **30** with iodine and pyridine [58-60]. The chromone **1** condenses with aldehydes in the presence of sodium alkoxide to give the 2-vinylchromone **33** [48,61, 62], use of $(MeO)_2Mg$ in MeOH in this Aldol condensation giving a slightly higher yield [63]. ChrMe gives the enamine **34** with dimethylformamide dimethyl acetal (DMFDA) in the presence of pyridine [64], and nitrone **35** with *p*-nitroso-*N,N*-dimethylaniline in the presence of EtONa [65,66]. The nitrone **35** also arises from the treatment of **30** with the aforesaid aniline in the presence of a base [58,59]. ChrMe has been acylated by diethyl oxalate to **31** in the presence of sodium in ether [46,66] as well as LDA in HMPT-THF [63]. A Japanese group [67] has shown that treatment of **1** with LDA followed by addition of an electrophile R^+ gives $ChrCH_2R$ (R = alkyl or acyl). A British group [68] has extensively studied the generation of the anion from 2,6-dimethylchromone with LDA and addition of several electrophiles thereon. Addition of benzoyl chloride or ethyl chloroformate gives **37** (R = COPh or CO_2Et, X = H). When ethyl benzoate or diethyl carbonate is added to a solution of LDA followed by addition of 2,6-dimethylchromone, the 2,3-disubstituted chromone **37** (R = H, X = COPh or CO_2Et) is obtained, the latter with X as CO_2Et being accompanied by a small amount of bis(2,6-dimethyl-4-oxo-4*H*-1-benzopyran-3-yl) ketone. Selenium dioxide oxidises **1** to the aldehyde **32** [28,37,69] which is also obtainable by the acid hydrolysis of the nitrone **35** [58,59] as well as by refluxing **29** in EtOH-$AgNO_3$ [57]. The nitrone **36** is obtained by reacting **32** with PhNHOH.

The pyridinium methylid, generated from **30** in the presence of a base, undergoes [3+2]cycloaddition with DMAD and ethyl propiolate, the cycloadducts rapidly aromatising to the indolizines **38** and **39**, respectively [70]. Similar cycloaddition of the said methylid with ethyl acrylate and acrylonitrile is also followed by dehydrogenation giving respectively the indolizines **39** and **40** [70]. The acid corresponding to the α-ketoester **31** condenses with *o*-phenylenediamine giving the benzopyrazine **41** [46]. The aldol condensate **42**, derived from the said acid and benzaldehyde, when refluxed with aniline in ethanol affords the quinoline derivative **44** [46]. Here 1,4-addition of aniline to the α,β-unsaturated ketone functionality of **42** gives **43** that undergoes cyclisation and spontaneous dehydrogenation to give **44** (Scheme 2).

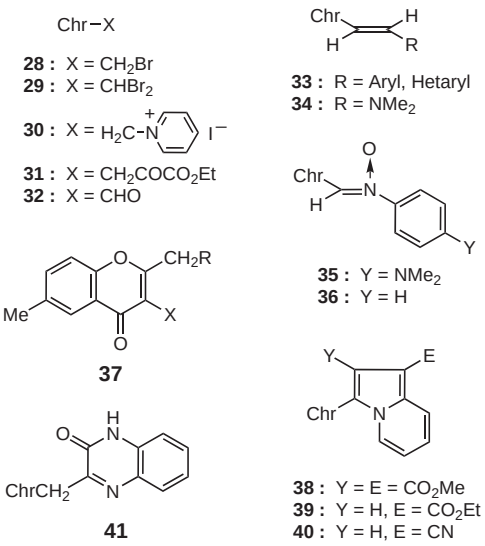
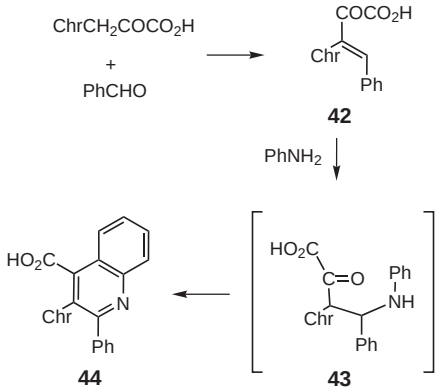


Figure 7

Scheme 2



The methyleneisobenzofuranone **45**, obtained by condensation of **1** with phthalic anhydride, rearranges in refluxing MeOH containing MeONa to the diketone **47** and gives with R^1NH_2 (R^1 = Ph, C_6H_4OMe-*p*, 4-pyridyl, $PhCH_2$) either **46** or **48** depending on the nature of the R^1 group and reaction conditions [71].

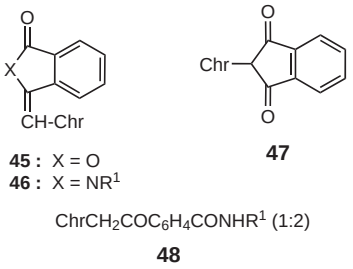


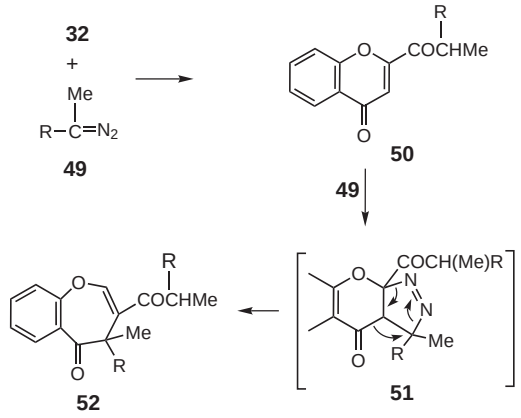
Figure 8

The compounds obtainable from the aldehyde **32**, 2-vinylchromones **33** and **34**, and nitrones **35** and **36** are described in the following sections.

VIII Compounds Obtainable through 2-Formylchromone **32**.

The aldehyde **32** is reduced by aluminium isopropoxide [72] and oxidised by Jones reagent [73] respectively to $ChrCH_2OH$ and $ChrCO_2H$, the latter being also obtainable from **32** through its oxime and the corresponding nitrile [73]. Zn-AcOH brings about reductive self-coupling of **32** to a streoisomeric mixture of ChrCH(OH)CH(OH)Chr [74]. Condensations of **32** or its benzene ring substituted analogues with malonic acid [72] and thiohydantoin [75] in the presence of pyridine have been reported. Different diazoalkanes behave differently towards 2-formylchromone [76]. Diazomethane transforms **32** into a mixture of 2-acetylchromone and (4-oxo-4*H*-1-benzopyran-2-yl)oxiran, both being formed in moderate yields. Diazoethane **49** (R = H) gives in addition to the homologous ketone **50** (R = H), the 1-benzoxepin derivative **52** (R = H), whereas diazopropane **49** (R = Me) converts **32** into **52** (R = Me). Here the diazoalkane **49** undergoes [3+2]cycloaddition with the 2,3-olefinic bond of the initially formed ketone **50** (R = H, Me) and the resultant pyrazoline intermediate **51** undergoes ring enlargement by elimination of nitrogen and migration of the carbonyl group to give the benzoxepin **52** (Scheme 3) [76].

Scheme 3



2-Formylchromone gives the dihydropyridine **53** with ethyl β-aminocrotonate [69] as well as with a mixture of ethyl acetoacetate and liquor NH_3 [58, 77] and the trisubstituted methane **54** with indole [74]. The chromone **32** gives Schiff's bases with aliphatic as well as aromatic primary amines [73,78] and hydrazones with several hydrazines [58,79,80]. The tosylhydrazone of **32** on Bamford-Stevens reaction gives $ChrCH=N_2$ that on keeping in AcOH at room temperature produces $ChrCH_2OAc$ [80]. The dialkyl ester of phosphorus acid [$HOP(OR)_2$, R = Me, Et, CHMe, Bu *etc*.] in the presence of the corresponding trialkyphosphite $P(OR)_3$ converts **32** to the phosphonic ester **55**. The compound **55** (R = Me) is hydrolysed by HBr-AcOH to **56** that can be reduced by red phosphorus-iodine in AcOH to the chromone-2-methane phosphonic acid **57** [81]. NaOCl in AcOH converts **32** into 3-chloro-2-formylchromone [37].

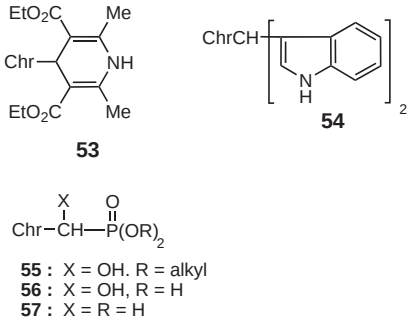


Figure 9

IX Reactions of 2-Vinylchromones.

Chloromethylation of 2-styrylchromone **58** at 3-position of its chromone moiety by paraformaldehyde-HCl is known [57]. Bromination of **58** (R = H, Me, OMe) with bromine in AcOH gives a stereoisomeric mixture of **59** [46] whereas that with pyridinium tribromide gives **59** along with its analogue having a bromo substitutent at 3-

position of the chromone moiety [82,83]. Debromination of **59** with triethylamine gives a mixture of *E*- and *Z*-2-(1-bromo-2-arylvinyl)chromone **60** [83]. *o*-Phenylenediamine converts **59** in refluxing EtOH-pyridine into the tetrahydropyrazine **61A** [46]. Each of the chromones **58-60** gives the disubstituted 1,2,3-triazole **62** when heated with sodium azide in DMF under reflux, the reaction with **58** being more efficient and giving higher yield [82]. In case of reaction with **60** (R = H, Cl), the tetrazole **63** is also formed as a minor product [82]. Hydrazine [84] or methylhydrazine [85] is likely to add to the pyran 2-position of **58**, the addition being followed by opening of the pyran ring and recyclisation to give 1-unsubstituted or 1-methyl-3-(2-hydroxyphenyl)-5-(2-arylvinyl) pyrazole derivative.

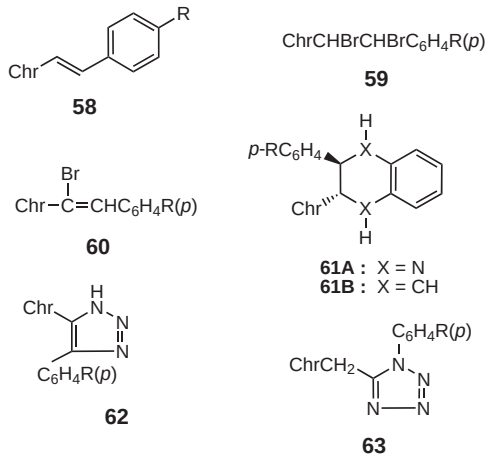
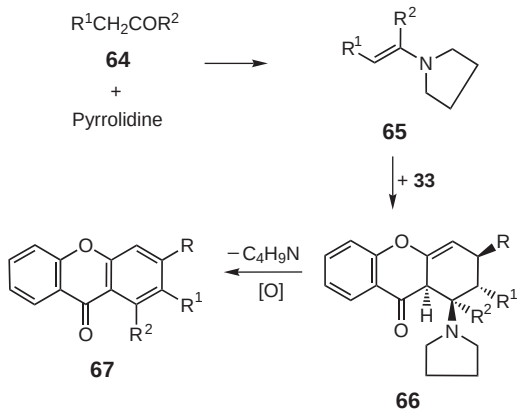


Figure 10

The nitrilimine $PhC^{+}=N-N^{-}-Ph$ undergoes [3+2]cycloaddition with the exocyclic olefinic bond of **58**, the negative pole of the former adding to the α-position of the styryl moiety [86]. Pyran 2,3- and exocyclic olefinic bonds together in 2-vinylchromone **33** constitute a diene system and its [4+2]cycloadditions with several alkenes reported till 1999 have been compiled in two review articles [87,88]. The chromone **33** (R = Me, Ph, substituted phenyl, 2-furyl, 2-thienyl) gives the xanthone **67** when refluxed in the oxocompound **64** (R^1 = H, R^2 = Me; R^1 = R^2 = Me; R^1 = Me, R^2 = H; R^1 = Et, R^2 = H) containing catalytic amount of pyrrolidine [89]. Here the enamine **65**, generated *in situ* from **64** and pyrrolidine, undergoes inverse electron demand Diels-Alder reaction with **33**; the resultant cycloadduct **66** on elimination of pyrrolidine and subsequent air oxidation affords **67** (Scheme 4) [89].

Scheme 4



2-Styrylchromone **58** functions as a 2π component in its Diels-Alder reaction with *o*-benzo-quinodimethane giving 2-[2-(3-aryl-1,2,3,4-tetrahydronaphthyl)]chromone **61B** that has been dehydrogenated to the corresponding flavone by bromination-dehydrobromination process [90]. Irradiation of **58** dissolved in benzene containing iodine affords the xanthone **68**. This transformation involves the (*E*)- to (*Z*)-photoisomerisation of **58** followed by electrocyclisation and oxidation [91]. The crowded heterocycle arising from sulfurisation of **68** (R = OMe) with P_2S_5 and subsequent coupling of the resultant thione with 9-azo-4,5-diazafluorene functions as an interesting bidentated ligand for osmimum, ruthenium and rhodium ions [91c]. Day light photooxidative cyclisation of **58** (R = H, Cl, CMe_3) to **68** is also possible [92]. Irradiation of 2-(pyridylvinyl)-chromone **69** (any one of X, X^1 and X^2 is N and the other two are CH) gives the fused heterocycle **70** [93].

The initially formed [4+2] cycloadducts of the dienamine **34** with *N*-phenyl-maleimide, 4-oxo-4*H*-1-benzopyran-3-carboxaldehyde, and -3-carboxylic acid also ultimately transform into xanthone derivatives [64]. The alkynes, unlike the alkenes, undergo [2+2]cycloaddition with exocyclic olefinic bond of **34**, the resultant adducts undergoing further tranformations. Thus, DMAD and dibenzoylacetylene give with **34** the xanthones **67** (R = R^1 = CO_2Me, R^2 = H) and **67** (R = R^1 = COPh, R^2 = H), respectively. Ethyl propiolate with **34** gives **67** (R = R^2 = H, R^1 = CO_2Et) admixed with the trisubstituted benzene **71** [64].

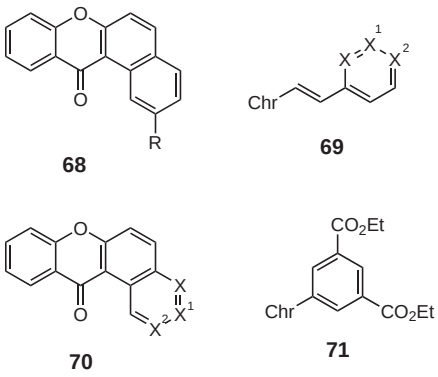


Figure 11

X Compounds Obtainable from the Nitrones **35** and **36**.

The present author [74] has studied the thermal transformations as well as dipolar cycloadditions of the nitrones **35** and **36**. The nitrone **35** thermally transforms into the 1-benzopyrano[2,3-*c*]quinoline-*N*-oxide **72**. The nitrone **36** undergoes [3+2]cycloaddition with ethoxyethene and *N*-phenylmaleimide giving the isoxazolidines **73** and **74**, respectively. Ethoxyethene and **35** together give a mixture of the 1-benzoxepins **75** and **76** presumably *via* their [3+2]cycloadduct.

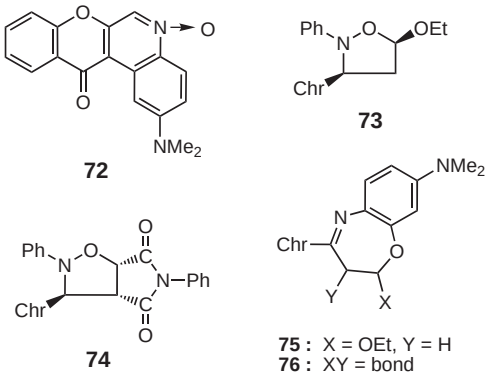


Figure 12

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