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CuSCN Catalyzed Conjugate Addition of Grignard Reagents to Substituted Coumarins with Dilithium Tetrachloromanganate

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The regioselective 1,4-addition of CuSCN catalyzed Grignard reagents to the substituted coumarins are reported. The Li_2MnCl_4 reagent is used to transmetallate magnesium by manganese. It adds regioselectively to coumarins and forms 1,4-addition products with higher yield under the atmosphere of nitrogen gas and at a lower temperature.

Keywords: Coumarin, Grignard reagent, Dilithium tetrachloromanganate, Conjugate addition, Transmetalation.

INTRODUCTION

The conjugate addition of organometallic reagents like organomagnesium and organolithium reagents to the α,β-unsaturated compounds in presence of copper(I) catalyst is one of the most important synthetic strategies for the formation of carbon-carbon bonds [1]. The utilization of Grignard reagents in organic chemistry, which are one of the most extensively used method, of organometallic compounds in the asymmetric conjugate addition has acquired much less assistance [2]. Even though exhaustive research over the past two decades, only limited selectivity in the conjugate addition of Grignard reagents were reported in contrast to dialkyl zinc reagents [3]. This is the most probable method because of the greater reactivity of organomagnesium reagents, which give rise to 1,2 and 1,4-additions without catalyst. Furthermore, the existence of various copper complexes in solution, for example, cuprate chemistry additionally, complicating the access to powerful enantiopure catalysis. Nowadays, there are few reports of high enantioselective compounds up to 99% ee which can be accomplished in the conjugate addition of organomagnesium reagents to the α,β-unsaturated carbonyl compounds by using catalytic quantity of asymmetric ferrocenyl diphosphine compounds and Cu(I) complexes [4]. The asymmetric conjugate addition reaction in presence of copper(I) complexes with Grignard reagents shows important process for the generation of chiral centers and has uses in synthesis [5-10]. The less reactive coumarin compounds were required to generate a new catalytic methodologies. The investigation begins with copper-catalyzed conjugate addition reaction of dialkylzinc compounds to coumarin employs phosphoramide ligands [11,12]. This catalytic method does not demonstrate to be more reactive and does not get in any output. When researchers turned their focus to asymmetric conjugate addition reaction with the highly reactive organomagnesium reagents, for instance, Josiphos ligand to the desired 1,4-addition product with 82% ee was achieved with full conversion [13]. However, the protocols that allow the insertion of alkyl groups at the newly generated asymmetric center in the structurally different 3,4-dihydropyran-2-ones. While conveying this challenge, chemist visualize the probability of applying 2*H*-pyran-2-ones [14] in conjunction with organometallic reagents to approach optically active dihydropyran-2-ones across the Cu(I) catalyzed conjugate addition reaction [15]. 2*H*-Pyran-2-ones present electron-deficient diene group are common substrate for [4+2] and [2+2] cyclo-addition reaction to generate bicyclic organic compounds [16]. However, in asymmetric conjugate addition reaction, the extra conjugation lowers the reactivity as compared with acyclic α,β-unsaturated esters [17]. According to our best of knowledge, asymmetric 1,4-addition of Grignard reagents to 2*H*-pyran-2-ones remain difficult to achieve. Such a kind of reaction could give an efficient, direct and resourceful method for the

synthesis of chiral 3,4-dihydropyran-2-ones. Additionally, the produced chiral intermediates would permit for various organic conversions in specific by addition to the enol ester functionality to approach highly different intermediates with good stereo and regiochemical control [18]. The asymmetric conjugate addition reaction of Grignard reagents in presence of a copper catalyst to cyclic enone has also been successfully performed with higher enantioselectivities by particular groups [19,20]. Generally, Grignard reagents are considered as developing anions able to simply react to heterocyclic double bonds. The nucleophilic 1,2-addition reaction to the carbonyl carbon atom that gives access to plenty of substituted alcohol derivatives [21]. For instance, benzophenone reacts with alkyl, cyclohexyl or isobutyl Grignard reagents giving rise to corresponding alcohols [22]. The bimolecular reduction of pinacolone to pinacol by using neopentyl magnesium halides here both the typical 1,2-addition and the 1,4-addition to the phenyl ring takes place with *t*-butyl Grignard reagents. O-Alkylation is rarely seen while Grignard reagents react with carboxylic oxygen atom, although it observed in reactants such as *ortho*-quinones [23], *o*-quinolacetates [24-26], 9,10-phenantraquinone [27] and benzyl [28] in a small extent. In previous reports, we observed unexpected reactivity of Grignard reagent like isopropyl-magnesium bromide and vinyl magnesium bromide with di(1,3-benzothiazol-2-yl)ketone, which gave an exclusive attack on the oxygen carbonyl atom [29,30]. The reactions of ketone and 2-methyl-1-propynylmagnesium bromide, it gave a mixture of C- and O-alkylation compounds in almost equal amounts. Conversely, allyl, alkyl or alkynyl Grignard reagents gives rise to complete the expected alcohol [31,32], O-alkylation and accompanying C-alkylation [33] obtained with azaheteroaryl ketones such as di(thiazol-2-yl)ketone or di(1,3-benzoxazol-2-yl)ketone.

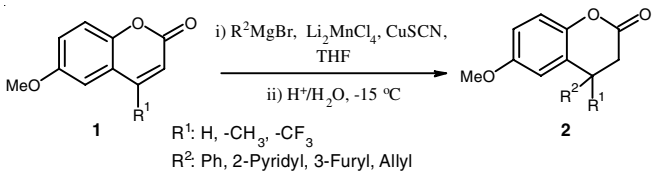
EXPERIMENTAL

In a three-necked round bottom flask were added alkyl/arylmagnesium bromide (10 mmol) to the dry THF (10 mL) and to which added Li_2MnCl_4 (10 mmol) over 20 min. Copper(I) thiocyanate (10 mol %) was added and stirred the content for 30 min. Substituted coumarin (10 mmol) in dry THF (5 mL) was added over 20 min at -15 ºC. When reaction completed (monitored on TLC), quenched with dil. HCl and salt solution of NH_4Cl under magnetic stirring for 15 min. The product was extracted with diethyl ether (03 × 10 mL) and dried over anhydrous Na_2SO_4. The boiling points were determined are uncorrected. IR spectra were determined on a Shimadzu Miracle 10 ATR instrument. ^{1}H NMR spectra were recorded on a Bruker 500 MHz spectrometer with $CDCl_3$ as a solvent and TMS as the internal standard. ^{13}C NMR spectra were recorded on Brucker 125 MHz spectrometer with $CDCl_3$ as the solvent. Column chromatography was conducted on silica gel 60 (70-230 mesh). Thin layer chromatography (TLC) was carried out on aluminium sheets precoated with silica gel.

Preparation of Li_2MnCl_4 solution: In a 250 mL round bottom flask were added LiCl (1M, 10.598 g) and $MnCl_2$ (1M, 15.730 g) and dried under vacuum at 250 ºC for about 3 h and the mixture were allowed to cool at room temperature followed by addition of 125 mL dry THF. The resulting solution kept under stirring overnight at room temperature, which is homogeneous brown coloured 1M solution of Li_2MnCl_4 and stable at room temperature for several days.

Preparation of Grignard geagent: In a 100 mL three-necked round bottom flask previously dried with heating gun and flushed with nitrogen gas were added magnesium turnings (0.243 g) and diethyl ether (50 mL), to which added iodine to initiate the reaction followed by added alkyl/aryl bromide (1.57 g) dropwise through septum. After the complete addition of alkyl/aryl halide, the mixture was stirred at room temperature for about 1 h to get homogenous 1M solution of Grignard reagent.

Addition of Grignard reagent to coumarin: In a 100 mL three-necked round bottom flask were added dry THF (10 mL), followed by addition of Grignard reagent (10 mmol) and Li_2MnCl_4 solution (10 mmol) to which added CuSCN (10 mol %) and dropwise addition of coumarin (10 mmol) in THF at -15 ºC, after complete addition of coumarin the progress of the reaction was studied by TLC and reaction were quenched with dil. HCl and stirred for 15 min. The product was extracted with diethyl ether (10 mL × 3) and dried over anhydrous Na_2SO_4 (**Scheme-I**).



Scheme-I: Addition of Grignard reagent to coumarin

6-Methoxy-4-phenyl-3,4-dihydro-2*H*-chromen-2-one (2a): Colourless liquid, m.f.: $C_{16}H_{14}O_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 2900. ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 7.27 (m, *J* = 8, 2.5 & 1 Hz, 5H), 6.70 (d, *J* = 2.5 Hz, 1H), 6.76 (dd, *J* = 8, 2.5 Hz, 1H), 7.05 (d, *J* = 8 Hz, 1H), 3.75 (s, 3H), 4.76 (t, 1H), 3.0 (s, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.54, 155.68, 114, 115.8, 144.86, 127.31, 109.74, 40.56, 37.79, 167.78, 140.49, 127.49, 128.68, 126.79. Anal. calcd. (found) %: C, 75.57 (75.55), H, 5.55 (5.58), O, 18.88 (18.87).

6-Methoxy-4-(pyridin-2-yl)-3,4-dihydro-2*H*-chromen-2-one (2b): Pale yellow liquid, m.f.: $C_{15}H_{13}NO_3$, IR (KBr, ν_{max}, cm^{-1}): 1100, 1745, 1600, 2900, 1660, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 6.87 (m, *J*= 8.5, 2.7 & 1.2 Hz, 1H), 7.52 (m, *J* = 8.5 & 2.7 Hz, 1H), 7.11 (m, *J* = 8.5, 2.7 Hz, 1H), 8.62 (m, *J* = 8.5, 2.7 & 1.2 Hz, 1H), 4.69 (t, *J* = 7 Hz, 1H), 3.05 (d, *J* = 7 Hz, 2H), 3.75 (s, 3H), 6.70 (d, *J* = 2.5 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J*= 8 Hz, 1H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 164.37, 125.06, 137.53, 121.96, 148.74, 37.29, 38.50, 168.82, 145.22, 116.45, 114.10, 156.08, 109.74, 126.54, 55.54. Anal. calcd. (found) %: C, 70.58 (70.59), H, 5.13 (5.12), N, 5.49 (5.50), O, 18.80 (18.79).

4-(Furan-3-yl)-6-methoxy-3,4-dihydro-2*H*-chromen-2-one (2c): Yellow liquid, m.f.: $C_{14}H_{12}O_4$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 2900, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 7.43 (dd, *J* = 7.5 & 1.5 Hz, 1H), 6.39 (dd, *J* = 7.5 & 1.5 Hz, 1H), 7.39 (dd, *J* = 7.5 & 1.5 Hz, 1H), 3.75 (s, 3H), 6.70 (d, *J* = 8 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz,

1H), 4.76 (t, *J* = 7 Hz, 1H), 3.05 (d, *J* = 7 Hz, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.54, 155.98, 114.24, 116.71, 144.67, 125.87, 110.78, 38.96, 38.17, 168.60, 127.81, 143.13, 112.38, 142.73. Anal. calcd. (found) %: C, 68.85 (68.83), H, 4.95 (4.96), O, 26.20 (26.21).

6-Methoxy-4-(prop-2-en-1-yl)-3,4-dihydro-2*H*-chromen-2-one (2d): Colourless liquid, m.f.: $C_{13}H_{14}O_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 3100, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 3.75 (s, 3H), 6.84 (d, *J* = 8 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), 3.70 (m, *J* = 7 Hz, 1H), 3.04 (d, *J* = 7 Hz, 2H), 2.28 (t, *J* = 7 Hz, 2H), 5.75 (m, *J* = 10 & 15 Hz, 1H), 4.99 (d, *J* = 10 & 15 Hz, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.54, 155.37, 113.80, 116.40, 148.13, 126.08, 110.14, 31.70, 35.49, 168.86, 36.03, 135.10, 117.14. Anal. calcd. (found) %: C, 71.54 (71.56), H, 6.47 (6.46), O, 21.99 (21.98).

6-Methoxy-4-methyl-4-phenyl-3,4-dihydro-2*H*-chromen-2-one (2e): Colourless liquid, m.f.: $C_{17}H_{16}O_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 2900, ^{1}H NMR, (500 MHz, $CDCl_3$) δ ppm: 7.26 (m, *J* = 8, 2.5 &1 Hz, 5H), 1.63 (s, 3H), 3.05 (s, 2H), 3.75 (s, 3H), 6.70 (d, *J* = 2.5 Hz, 1H), 6.76 (dd, *J* = 8, 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 157.55, 114.60, 117.36, 148.83, 134.22, 111.36, 37.44, 43.82, 168.14, 148.15, 127.02, 128.62, 126.90. Anal. calcd. (found) %: C, 76.10 (76.12), H, 6.01 (6.00), O, 17.89 (17.88).

6-Methoxy-4-methyl-4-(pyridin-2-yl)-3,4-dihydro-2*H*-chromen-2-one (2f): Yellow liquid, m.f.: $C_{16}H_{15}NO_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 2900, 1660, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 7.41 (m, *J* = 8.5, 2.7 & 1.2 Hz, 1H), 7.54 (m, *J* = 8.5 & 2.7 Hz, 1H), 7.10 (m, *J* = 8.5 & 2.7 Hz, 1H), 8.51 (m, *J* = 8.5, 2.7 & 1.2 Hz, 1H), 1.63 (s, *J* = 7 Hz, 3H), 3.04 (s, 2H), 3.75 (s, 3H), 6.70 (d, *J* = 8 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 157.46, 113.42, 118.0, 149.85, 137.50, 111.35, 25.04, 37.55, 46.86, 168.14, 169.21, 120.18, 138.36, 121.67, 149.04. Anal. calcd. (found) %: C, 71.36 (71.37), H, 5.61 (5.60), N, 5.20 (5.19), O, 17.82 (17.83).

4-(Furan-3-yl)-6-methoxy-4-methyl-3,4-dihydro-2*H*-chromen-2-one (2g): Yellow liquid, m.f.: $C_{15}H_{14}O_4$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 2900, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 7.43 (dd, *J* = 7.5 & 1.5 Hz, 1H), 6.39 (dd, *J*= 7.5 & 1.5 Hz, 1H), 7.39 (dd, *J* = 7.5 & 1.5 Hz, 1H), 3.75 (s, 3H), 6.70 (d, *J* = 8 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), 1.63 (s, 3H), 3.05 (s, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 157.44, 113.75, 117.77, 148.84, 132.15, 111.67, 25.63, 35.74, 42.89, 167.47, 140.56, 110.66, 141.91, 136.92. Anal. calcd. (found) %: C, 69.76 (69.74), H, 5.46 (5.47), O, 24.78 (24.79).

6-Methoxy-4-methyl-4-(prop-2-en-1-yl)-3,4-dihydro-2*H*-chromen-2-one (2h): Colourless liquid, m.f.: $C_{14}H_{16}O_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 3100, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 3.75 (s, 3H), 6.89 (d, *J* = 2 Hz, 1H), 6.66 (dd, *J* = 8 & 2 Hz, 1H), 6.94 (d, *J* = 8 Hz, 1H), 3.05 (s, 2H), 1.49 (s, 3H), 2.16 (d, 2H), 5.75 (m, *J* = 15 & 9 Hz, 1H), 4.99 (d, *J*= 9, 15 & 2.5 Hz, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 157.88, 115.82, 118.53, 147.82, 133.80, 109.48, 37.55, 43.63, 167.88, 45.77, 133.59, 118.89, 25.8. Anal. calcd. (found) %: C, 72.39 (72.41), H, 6.94 (6.93), O, 20.66 (20.65).

6-Methoxy-4-phenyl-4-(trifluoromethyl)-3,4-dihydro-2*H*-chromen-2-one (2i): Pale yellow liquid, m.f. $C_{17}H_{13}O_3F_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1100, 1600, 2900, 950, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 7.28 (m, *J* = 8, 2.5 & 1 Hz, 5H), 3.07 (s, 2 H), 3.75 (s, 3H), 6.70 (d, *J* = 2.5 Hz, 1H), 6.76 (dd, *J* = 8, 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 156.90, 115.69, 117.59, 149.03, 128, 113.20, 47.22, 39.66, 168.11, 125.90, 140.17, 127.68, 128.29, 126.25, Anal. calcd. (found) %: C, 63.36 (63.37), H, 4.07 (4.06), O, 14.89 (14.88), F, 17.69 (17.70).

6-Methoxy-4-(pyridin-2-yl)-4-(trifluoromethyl)-3,4-dihydro-2*H*-chromen-2-one (2j): Yellow liquid, m.f. $C_{16}H_{12}NO_3F_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 1660, 950, 2900, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm:, 7.41 (m, *J*= 8.5, 2.7 & 1.2 Hz, 1 H), 7.54 (m, *J* = 8.5 & 2.7 Hz, 1H), 7.10 (m, *J* = 8.5 & 2.7 Hz, 1H), 8.51 (m, *J* = 8.5, 2.7 & 1.2 Hz, 1H), 3.04 (s, 2H) , 3.75 (s, 3H), 6.70 (d, *J* = 8 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 157.46, 117.12, 118.68, 149.18, 128.64, 114.13, 45.49, 123.39, 39.86, 168.11, 160.12, 124.17, 137.11, 122.07, 147.88. Anal. calcd. (found) %: C, 59.45 (59.44), H, 3.74 (3.75), O, 14.85 (14.84), F, 17.63 (17.64).

4-(Furan-3-yl)-6-methoxy-4-(trifluoromethyl)-3,4-dihydro-2*H*-chromen-2-one (2k): Yellow liquid, m.f.: $C_{15}H_{11}O_4F_3$, IR IR (KBr, ν_{max}, cm^{-1}): 1745, 1100, 950, 2900, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 7.43 (dd, *J*= 7.5 & 1.5 Hz, 1H), 6.39 (dd, *J*= 7.5 & 1.5 Hz, 1H), 7.39 (dd, *J* = 7.5 & 1.5 Hz, 1H), 3.75 (s, 3H), 6.70 (d, *J* = 8 Hz, 1H), 6.76 (dd, *J* = 8 & 2.5 Hz, 1H), 7.01 (d, *J* = 8 Hz, 1H), 3.05 (s, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 156.91, 116.07, 118.78, 149.51, 123.19, 114.75, 125.55, 54.84, 37.08, 167.63, 90, 114.85, 144.35, 136. Anal. calcd. (found) %: C, 57.70 (57.71), H, 3.55 (3.54) O, 20.50 (20.51), F, 18.25 (18.24).

6-Methoxy-4-(prop-2-en-1-yl)-4-(trifluoromethyl)-3,4-dihydro-2*H*-chromen-2-one (2l) Pale yellow liquid, m.f.: $C_{14}H_{13}O_3F_3$, IR (KBr, ν_{max}, cm^{-1}): 1745, 1600, 1100, 3100, 950, ^{1}H NMR (500 MHz, $CDCl_3$) δ ppm: 3.75 (s, 3H), 6.89 (d, *J* = 2 Hz, 1H), 6.66 (dd, *J* = 8 & 2 Hz, 1H), 6.94 (d, *J* = 8 Hz, 1H), 2.65 (s, 2H), 2.16 (d, *J* = 7 Hz, 2H), 5.75 (m, *J* = 15 & 9 Hz, 1H), 4.99 (d, *J* = 9, 15 & 2.5 Hz, 2H), ^{13}C NMR (125 MHz, $CDCl_3$) δ ppm: 55.46, 156.54, 114.82, 118.53, 150.82, 123.30, 41.83, 113.39, 37.55, 169.44, 37.99, 134.09, 118.60, 121.86. Anal. calcd. (found) %: C, 58.74 (58.75), H, 4.58 (4.57), O, 16.77 (16.78), F, 19.91 (19.90).

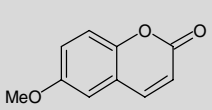
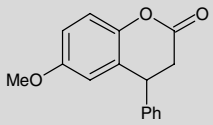
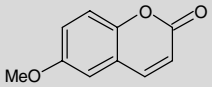
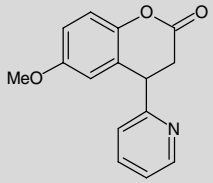
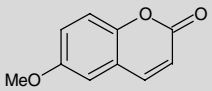
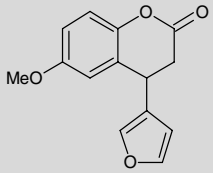
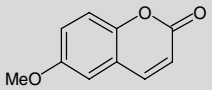
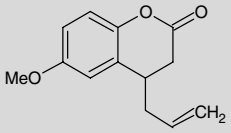
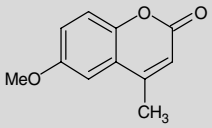
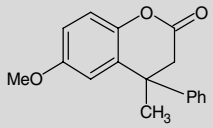
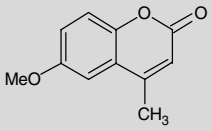
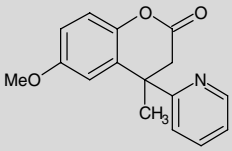
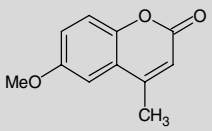
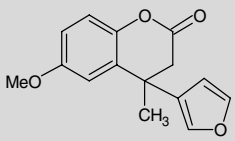
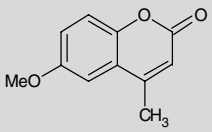
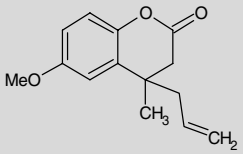
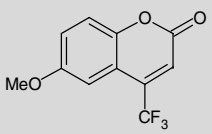
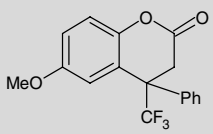
RESULTS AND DISCUSSION

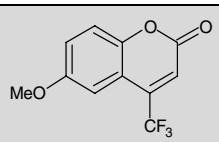
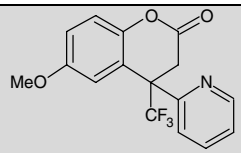
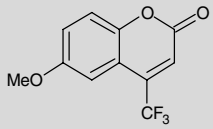
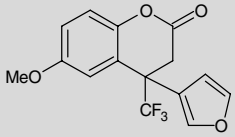
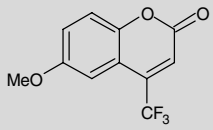
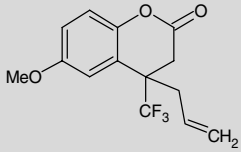
To account for the significance of solvent in this process, the reactions were carried out in the absence of Li_2MnCl_4 in which reaction requires a longer time and lower yields. However, the reaction was carried out in the presence of Li_2MnCl_4 and different solvents like THF, diethyl ether, and 1,4-dioxane wherein the reaction it gives different yields and high regioselectivity (Table-1). Table-2 shows the results obtained from using different reaction parameters for the synthesis of compounds **2a** to **2l**. It has also been observed that substituted coumarin gives results with Grignard reagents in the presence

TABLE-1
EFFECTS OF SOLVENTS FOR THE SYNTHESIS COMPOUND **2a** AND **2e**

Entry	Reagent	Solvent	Compound **2a**		Compound **2e**	
			Time (min)	Yield (%)	Time (min)	Yield (%)
1	Li_2MnCl_4	THF	30	70	45	68
2	Li_2MnCl_4	Diethyl ether	40	66	45	60
3	Li_2MnCl_4	1,4-Dioxane	45	64	55	58
4	–	THF	35	48	45	52
5	–	Diethyl ether	45	45	50	48
6	–	1,4-Dioxane	50	42	60	45

TABLE-2
SYNTHESIS OF COMPOUNDS **2a** to **2l**

Compound	Reactant	Product	Time (min)	Yield (%)
2a			30	70
2b			40	66
2c			40	62
2d			35	65
2e			45	68
2f			45	64
2g			50	62
2h			45	60
2i			50	72

2j			55	69
2k			50	65
2l			45	75

of homogeneous solution of Li_2MnCl_4 with copper thiocyanate. The stoichiometry of the reactants to the Grignard reagents used was 1:1. The nucleophilic attack of Grignard reagent was occurred at 1,4-position of substituted coumarin to yield final products. It has also been found that the poor regioselectivity obtained in absence of Li_2MnCl_4 reagent and mixture of products were formed with 1,2-addition.

Conclusion

In conclusion, it is observed that 1,4-addition of Grignard reagents to the various substituted coumarins in presence of dilithium tetrachloromanganate reagent for transmetallation under nitrogen atmosphere that results in higher yields. The simple workup of reaction, higher yields and good regioselectivity of the reaction makes this reagent the most appropriate option to the reported methods.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

REFERENCES

1. A. Alexakis and C. Benhaim, *Eur. J. Org. Chem.*, **2002**, 3221 (2002); https://doi.org/10.1002/1099-0690(200210)2002:19<3221::AID-EJOC3221>3.0.CO;2-U
2. S. Woodward, *Angew. Chem. Int. Ed.*, **44**, 5560 (2005); https://doi.org/10.1002/anie.200501204
3. G.M. Villacorta, C.P. Rao and S.J. Lippard, *J. Am. Chem. Soc.*, **110**, 3175 (1988); https://doi.org/10.1021/ja00218a028
4. B.L. Feringa, R. Badorrey, D. Pena, S.R. Harutyunyan and A.J. Minnaard, *J. Proc. Natl. Acad. Sci. USA*, **101**, 5834 (2004); https://doi.org/10.1073/pnas.0308008101
5. T. Jerphagnon, M.G. Pizzuti, A.J. Minnaard and B.L. Feringa, *Chem. Soc. Rev.*, **38**, 1039 (2009); https://doi.org/10.1039/b816853a
6. D. Martin, S. Kehrli, M. d'Augustin, H. Clavier, M. Mauduit and A. Alexakis, *J. Am. Chem. Soc.*, **128**, 8416 (2006); https://doi.org/10.1021/ja0629920
7. A. Alexakis, J.E. Bäckvall, N. Krause, O. Pàmies and M. Diéguez, *Chem. Rev.*, **108**, 2796 (2008); https://doi.org/10.1021/cr0683515
8. F. Lopez, S.R. Harutyunyan, A. Meetsma, A.J. Minnaa Rd and B.L. Feringa, *Angew. Chem. Int. Ed.*, **44**, 2752 (2005); https://doi.org/10.1002/anie.200500317
9. R.D. Mazery, M. Pullez F. Lopez, S.R. Harutyunyan, A.J. Minnaard and B.L. Feringa, *J. Am. Chem. Soc.*, **127**, 9966 (2005); https://doi.org/10.1021/ja053020f
10. T.E. Schmid, S. Drissi-Amraoui, C. Crévisy, O. Baslé and M. Mauduit, *Beilstein J. Org. Chem.*, **11**, 2418 (2015); https://doi.org/10.3762/bjoc.11.263
11. J.F. Teichert and B.L. Feringa, *Angew. Chem. Int. Ed.*, **49**, 2486 (2010); https://doi.org/10.1002/anie.200904948
12. B.L. Feringa, M. Pineschi, L.A. Arnold, R. Imbos and A.H.M. de Vries, *Angew. Chem. Int. Ed. Engl.*, **36**, 2620 (1997); https://doi.org/10.1002/anie.199726201
13. J.N. Moorthy, P. Venkatakrishnan, S. Sengupta and M. Baidya, *Org. Lett.*, **8**, 4891 (2006); https://doi.org/10.1021/ol0619260
14. K. Afarinkia, V. Vinader, T.D. Nelson and G.H. Posner, *Tetrahedron*, **48**, 9111 (1992); https://doi.org/10.1016/S0040-4020(01)85607-6
15. B.L. Feringa, *Acc. Chem. Res.*, **33**, 346 (2000); https://doi.org/10.1021/ar990084k
16. K.C. Nicolaou, J.J. Liu, C.-K. Hwang, W.-M. Dai and R.K. Guy, *J. Chem. Soc. Chem. Commun.*, 1118 (1992); https://doi.org/10.1039/c39920001118
17. A.G. Csákÿ, G. Herrán and M.C. Murcia, *Chem. Soc. Rev.*, **39**, 4080 (2010); https://doi.org/10.1039/b924486g
18. F. Lopez, S.R. Harutyunyan, A.J. Minnaard and B.L. Feringa, *J. Am. Chem. Soc.*, **126**, 12784 (2004); https://doi.org/10.1021/ja046632t
19. Z. Ma, F. Xie, H. Yu, Y. Zhang, X. Wu and W. Zhang, *Chem. Commun.*, **49**, 5292 (2013); https://doi.org/10.1039/C3CC42088D
20. G.S. Silverman and P.E. Rakita, Handbook of Grignard Reagents, Dekker; CRC Press: New York, NY, USA (1996).
21. T. Hoim and I. Crossland, ed.: H.G. Richey Jr., Mechanistic Featuresof the Reactions of Organomagnesium Compounds, In: Grignard Reagents-New Devlopments, John Wiley & Sons: Chichster, UK (2000).
22. T. Laird, eds.: D. Barton, W.D. Ollis and J.F. Stoddard, Aromatic Ketones in Comprehensive Organic Chemistry, Pergamon Press: Oxford, UK; volume 1, Chap. 5.4; pp. 1174-1181 (1979).
23. C. Blomberg, H.H. Grootveld, T.H. Gerner and F. Bickelhaupt, *J. Organomet. Chem.*, **24**, 549 (1970); https://doi.org/10.1016/S0022-328X(00)84483-6

24. F. Wessely and J. Kotlan, *Monatsh. Chem.*, **84**, 124 (1953); https://doi.org/10.1007/BF00899130
25. B. Miller, *J. Org. Chem.*, **42**, 1402 (1977); https://doi.org/10.1021/jo00428a030
26. B. Miller, *J. Org. Chem.*, **42**, 1408 (1977); https://doi.org/10.1021/jo00428a031
27. D. Wege, *Aust. J. Chem.*, **24**, 1531 (1971); https://doi.org/10.1071/CH9711531
28. T. Holm, R. Stomberg, S. von Unge and A.-B. Wassgren, *Acta Chem. Scand. Ser. B*, **41**, 278 (1987); https://doi.org/10.3891/acta.chem.scand.41b-0278
29. C. Boga, L. Forlani and P.E. Todesco, *Tetrahedron Lett.*, **38**, 4845 (1997); https://doi.org/10.1016/S0040-4039(97)01009-5
30. C. Boga, L. Forlani and P.E. Todesco, *Gazz. Chim. Ital.*, **127**, 197 (1997).
31. C. Boga, R. Stengel, R. Abdayem, E. Del Vecchio, L. Forlani and P.E. Todesco, *J. Org. Chem.*, **69**, 8903 (2004); https://doi.org/10.1021/jo048948p
32. B.F. Abdel-Wahab, H.A. Mohamed and A.A. Farhat, *Org. Commun.*, **7**, 1 (2014).
33. T. Jerphagnon, G. Pizzuti, A.J. Minnaard and B.L. Feringa, *Chem. Soc. Rev.*, **38**, 1039 (2009); https://doi.org/10.1039/B816853A