HETEROCYCLES, Vol. 85, No. 3, 2012, pp. 697 - 704. © 2012 The Japan Institute of Heterocyclic Chemistry
Received, 8th January, 2012, Accepted, 2nd February, 2012, Published online, 10th February, 2012
DOI: 10.3987/COM-12-12422

A NEW SYNTHETIC APPROACH TO AZULENO[2,1-*b*]PYRIDIN-4(*1H*)-ONES

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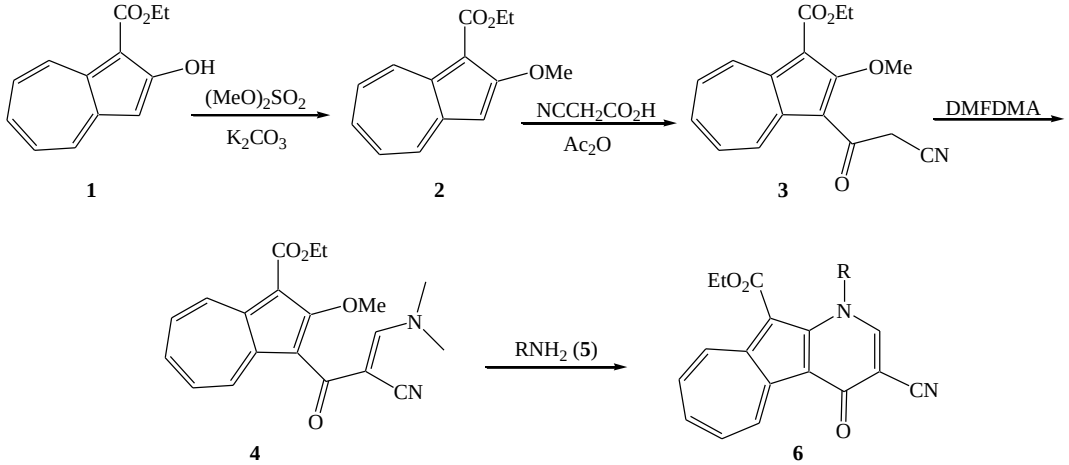
Abstract − 3-(Dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)-acrylonitrile (**4**) as new synthons directed to heterocycle-fused azulene was obtained by the condensation of ethyl 1-cyanoacetyl-2-methoxy-azulene-3-carboxylate (**3**) and *N*,*N*-dimethylformamide dimethyl acetal (DMFDMA). Reaction of this *β*–enaminone with primary amines (**5**) in EtOH at fluxing then affords *N*-substituted 3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]-pyridin-4(*1H*)-one derivatives (**6**) in good yields by a tandem addition-elimination-S_NAr reaction. This reaction provides a new procedure for synthesis of pyridinone-fused azulenes.

A variety of heterocycle-fused azulenes have so far been obtained on the viewpoints of chemical properties and physiological activities by several synthetic methods.[1-4] In a previous paper, we reported that 1-acetyl-2-(bromomethyl)azulene reacted with anilines or thioacetamide, as well as 1-acetyl-2-methoxyazulene reacted with arylhydrazines, to give 2-aryl-3methylazuleno[1,2-*c*]pyrroles[5] or azuleno[1,2-*c*]thiophenes,[6] and azuleno[1,2-*d*]pyrazoles,[7] respectively. More recently, the azuleno[2,1-*d*]pyrimidines,[8] azuleno[2,1-*d*]pyrimidinones,[9] and azuleno[2,1-*b*]pyrans[10] have been successfully prepared by our group. Furthermore, azuleno[2,1-*b*]pyridin-4(1*H*)-one was prepared by condensation of 2-aminoazulene with diethyl(ethoxymethylene)malonate, follow by cyclization reaction.[11]

On the other hand, the pyridin-4-(*1H*)-ones are key structural elements in medicinal chemistry and versatile intermediates in organic synthesis.[12] Many derivatives have been studied as potential treatments for a range of diseases because of their important biological properties, such as antibacterial[13] antiviral,[14] antiplatelet,[15] antitumor,[16] and other pharmacological activities.

In this work, we describe a facile synthesis of *N*-substituted 3-cyano-10-ethoxycarbonylazuleno [2,1-*b*]pyridin-4(*1H*)-one derivatives (**6**) by a tandem addition-elimination-S_NAr reaction of 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)acrylonitrile (**4**), easily preparation by the condensation of ethyl 1-cyanoacetyl-2-methoxyazulene-3-carboxylate (prepared form the ethyl 2-thdroxyazulene-1-carboxylate (**1**) as the stating material, by methylation and cyanoacetylation) and *N*,*N*-dimethylformamide dimethyl acetal (DMFDMA), with primary amines (**5**) (Scheme 1).



Scheme 1

First, the ethyl 1-cyanoacetyl-2-methoxy-3-azulenecarboxylate (**3**) by one-pot approach, employing cycanoacetic acid in acetic anhydride for the introduction of the cyanoacetyl functionality, provides quick and easy access to cyanoacetylated ethyl 2-methoxyazulene-1-carboxylate (**2**), preparation by the methylation of ethyl 2-hydroxyazulene-1-carboxylate (**1**) with dimethyl sulfate, in 86% yield as deep red prism (mp 127-128 ºC). Its structure was determined from the spectral data as well as elemental analysis ($C_{17}H_{15}NO_4$). In the IR spectrum, two carbonyl signals at 1651 and 1647 cm^{-1} and one cyano signals at 2219 cm^{-1} are observed. The ^1H NMR spectrum shows singlet peak at δ 4.28 (2H) for $COCH_2CN$, and seven-membered protons are seen at signals at δ 7.88-8.03 (3H, m), 9.42 (1H, d, J= 10.2 Hz), and 9.94 (1H, d, J = 10.4 Hz) together with ethoxycarbonyl protons at δ 1.62 (3H, t, J = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.64 (2H, q, J = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), and methoxy at δ 4.39 (3H, s, OCH_3).

Next, the key intermediate, synthesis for heterocycle-fused azulenes, 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)acrylonitrile (**4**) was obtained by the condensation of ethyl 1-cyanoacetyl-2-methoxy-3-azulenecarboxylate (**3**) with DMFDMA, in 82% yield as deep red prism (mp 146-148 ºC). Its structure was determined from the spectral data as well as elemental analysis ($C_{20}H_{20}N_2O_4$). The ^1H NMR spectrum shows singlet peak at δ 3.37 (3H, s, NCH_3), 3.60 (3H, s, NCH_3) and 7.87 (1H, s) for dimethylaminoacrylonitrile.

Finally, we demonstrated that 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)-

acrylonitrile (**4**) could be easily transformed into the corresponding azuleno[2,1-*b*]pyridin-4(*1H*)-one derivatives (**6**) (Scheme 1).

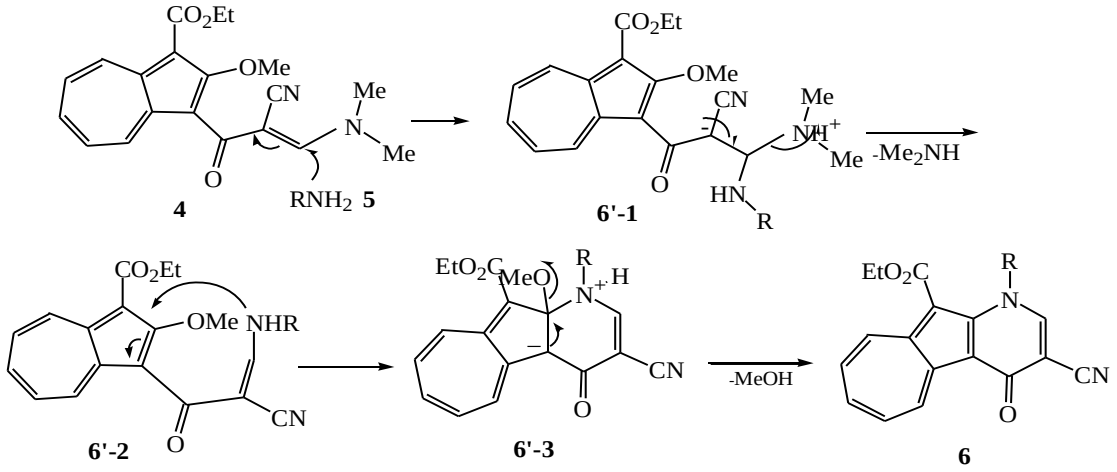
As shown in Table 1, the reaction was successful for primary amines (**5**) incorporating alkyl (entries 1-3), and aromatic (entries 4-10) R groups carrying either electron-donating or electron-withdrawing substituents reacted efficiently giving good yields (63-92%). Furthermore, cyclohexylamine and hindered aromatic amines could react smoothly to give the corresponding products **6a-6m** in moderate yields (54-62%) with longer reaction time (entries 11-13), yields decreased as the steric hindrance grew larger.

Table 1. Synthesis of *N*-substituted 3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-ones **6** *

Entry	**5** / R	Time / h	Product	Yield / %
1	**5a** Me	3	**6a**	86
2	**5b** Et	3	**6b**	83
3	**5c** Benzyl	2	**6c**	92
4	**5d** C_6H_5	4	**6d**	79
5	**5e** 4-MeC_6H_4	4	**6e**	83
6	**5f** 4-$MeOC_6H_4$	4	**6f**	85
7	**5g** 4-ClC_6H_4	5	**6g**	84
8	**5h** 4-FC_6H_4	6	**6h**	80
9	**5i** 4-$CO_2EtC_6H_4$	8	**6i**	68
10	**5j** 4-$NO_2C_6H_4$	10	**6j**	63
11	**5k** 2-$MeOC_6H_4$	12	**6k**	62
12	**5l** 2-FC_6H_4	18	**6l**	58
13	**5m** Cyclohexyl	24	**6m**	54

* Reaction conditions: 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)acrylonitrile (**4**, 1 mmol), amine (**5,** 1.1 mmol), EtOH (30 mL), at reflux.

The proposed mechanism of the process is summarized in scheme 2. The sequence involves an initial conjugate addition of the amine **5** to enaminone **4** followed by elimination of the dimethylamino group to give adduct **6'-2**. Finally, an intramolecular nucleophilic aryl substitution of the 2-methoxy of azulenyl group by attack of NH group leads to afford **6** by a S_NAr ring closure reaction.



Scheme 2

In conclusion, we have successfully developed facile and efficient method to prepare a series of *N*-substituted 3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-ones *via* tandem addition-elimination-S_NAr reaction of 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)-acrylonitrile with primary amines in moderate to good yields. Further investigations to elaborate the scope of this methodology and to show the synthetic utility of the heterocycle-fused azulene derivatives obtained are currently in progress in our laboratory.

EXPERIMENTAL

All melting points were determined on a Yanako MP-3 apparatus and are uncorrected. ^{1}HNMR spectra were recorded on a Bruker spectrometer (400 MHz). IR spectra were measured on Shimadzu IR-740 spectrophotometer. Elemental analyses were performed on EA 2400II elemental analyzer (Perkin-Elmer).

Preparation of ethyl 2-Methoxyazulene-1-carboxylate (2)

To the mixture of ethyl 2-hydroxyazulene-1-carboxylate[17] **1** (21.6 g, 0.1 mol), dimethyl sulfate (18.9 g, 0.15 mol) and MeCN (250 mL) was added anhydrous potassium carbonate (27.6 g, 0.2 mol) with stirring. After stirred under reflux for 6 h. The reaction mixture was filtered. The filtrate was concentrated and the water (30 mL) was added. The solid was filtered and recrystallized from benzene to give 20 g (87%) of **2**, as deep red crystals. mp 66-67 ºC (Lit.[17] mp 64-65 ºC); IR (KBr, cm^{-1}): *v* 1658 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.57 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.24 (3H, s, OCH_3), 4.57 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 6.89 (1H, s), 7.61-7.72 (2H, m), 7.54 (1H, dd, *J* = 9.6, 9.6 Hz), 8.30 (1H, s), 9.48 (1H, d, *J* = 9.2 Hz), 8.30 (1H, d, *J* = 9.6 Hz), 10.41 (1H, d, *J* = 9.6 Hz). *Anal*. Calcd for $C_{14}H_{14}O_3$: C 73.03, H 6.13. Found: C 73.21, H 6.28.

Preparation of ethyl 1-cyanoacetyl-2-methoxyazulene-3-carboxylate (3)

Ethyl 2-methoxyazulene-1-carboxylate **2** (10.0 g, 50.0 mmol) in AcOH (20 mL) was added slowly to a hot (50 ºC) mixture of cyanoacetic acid (6.1 g, 60.0 mmol) and acetic anhydride (25 mL). After complete addition the reaction mixture was heated at 60 ºC for 2 h. and was then allowed to tool. Then water (250 mL) was added and stirred for 30 min. The solid was filtered and recrystallized from EtOH to give 12.8 g (86%) of **3**, as deep red prisms. mp 127-128 ºC; IR (KBr, cm^{-1}): *v* 2219 (CN), 1651 (C=O), 1647 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.62 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.28 (2H, s), 4.39 (3H, s, OCH_3), 4.64 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.88-8.03 (3H, m), 9.42 (1H, d, *J* = 10.2 Hz), 9.94 (1H, d, *J* = 10.4 Hz). *Anal*. Calcd for $C_{17}H_{15}NO_4$: C 68.68, H 5.09, N 4.71. Found: C 68.79, H 5.15, N 4.86.

Preparation of 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)acrylonitrile (4)

To a solution of ethyl 1-cyanoacetyl-2-methoxyazulene-3-carboxylate **3** (5.9 g, 20.0 mmol) in DMF (20 mL) was added DMFDMA (3.8 g, 30.0 mmol) and the mixture was heated at 80 ºC for 3 h. After cooling to room temperature, then water (50 mL) was added and stirred for 5 min. The solid was filtered and recrystallized from EtOH to give 5.7 g (82%) of **4**, as orange prisms. mp 146-148 ºC; IR (KBr, cm^{-1}): *v* 2201 (CN), 1655 (C=O), 1629 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.56 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.37 (3H, s, NCH_3), 3.60 (3H, s, NCH_3), 4.30 (3H, s, OCH_3), 4.56 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.62 (1H, dd, *J* = 9.6, 9.6 Hz), 7.70 (1H, dd, *J* = 9.6, 9.6 Hz), 7.80 (1H, dd, *J* = 9.6, 9.6 Hz), 7.87 (1H, s), 8.58 (1H, d, *J* = 10.0 Hz), 9.48 (1H, d, *J* = 10.0 Hz). *Anal*. Calcd for $C_{20}H_{20}N_2O_4$: C 68.17, H 5.72, N 7.95. Found: C 68.26, H 5.87, N 8.13.

Preparation of *N*-substituted 3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one derivatives. General procedure : A mixture of 3-(dimethylamino)-2-(2-methoxy-1-ethoxycarbonylazulen-3-oyl)-acrylonitrile (**4**, 1.0 mmol), amine (**5**, 1.1 mmol) in EtOH (30 mL) was heated to reflux under stirring for the given time (Table 1). After completion (by TLC), the reaction mixture was cooled to room temperature, then water (20 mL) was added to the mixture and stirred for 5 min. The solid was filtered and recrystallized to afford the corresponding products. The physical and spectra data of the compounds **6a-6m** are as follows:

***N*-Methyl-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one** (**6a**)**:** Orange needles (from EtOH). mp 242-244 ºC; IR (KBr, cm^{-1}): *v* 2219(CN), 1658 (C=O), 1633 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.64 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.68 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.16 (3H, s, CH_3), 7.93 (1H, dd, *J* = 9.2, 9.2 Hz), 8.03 (1H, dd, *J* = 9.2, 9.2 Hz), 8.12 (1H, dd, *J* = 9.2, 9.2 Hz), 8.10 (1H, s), 9.18 (1H, d, *J* = 10.4 Hz), 10.45 (1H, d, *J* = 9.2 Hz). *Anal*. Calcd for $C_{18}H_{14}N_2O_3$: C 70.58, H 4.61, N 9.15. Found: C 70.63, H 4.74, N 9.29.

***N*-Ethyl-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one** (**6b**)**:** Orange needles (from EtOH). mp 165-167 ºC; IR (KBr, cm^{-1}): *v* 2216(CN), 1655 (C=O), 1637 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.59-1.69 (6H, m), 4.69 (2H, q, *J* = 7.2 Hz, $N\underline{CH_2}CH_3$), 4.69 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.90 (1H, dd, *J* = 9.2, 10.0 Hz), 8.00 (1H, dd, *J* = 9.2, 9.2 Hz), 8.09 (1H, dd, *J* = 9.2, 9.2 Hz), 8.16 (1H, s), 9.08 (1H, d, *J* = 10.0 Hz), 10.46 (1H, d, *J* = 9.2 Hz). *Anal*. Calcd for $C_{19}H_{16}N_2O_3$: C 71.24, H 5.03, N 8.74. Found: C 71.43, H 5.21, N 8.87.

***N*-Benzyl-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one** (**6c**)**:** Orange needles (from EtOH). mp 198-200 ºC; IR (KBr, cm^{-1}): *v* 2215(CN), 1657 (C=O), 1634 (C=O). ^{1}H-NMR ($CDCl_3$): δ 1.32

(3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 4.36 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 5.68 (2H, s), 7.05-7.08 (2H, m), 7.05-7.08 (2H, m), 7.31-7.34 (3H, m), 7.77 (1H, dd, *J* = 9.6, 9.6 Hz), 7.87-7.98 (2H, m), 8.03 (1H, s), 8.94 (2H, d, *J* = 8.7 Hz), 9.15 (1H, d, *J* = 10.5 Hz), 10.38 (1H, d, *J* = 9.9 Hz). *Anal*. Calcd for $C_{24}H_{18}N_2O_3$: C 75.38, H 4.74, N 7.33. Found: C 75.46, H 4.89, N 7.51.

***N*-Phenyl-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6d):** Orange needles (from EtOH). mp 276-278 ºC; IR (KBr, cm^{-1}): *v* 2216(CN), 1653 (C=O), 1628 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.15 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.70 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.62-7.66 (3H, m), 7.70-7.74 (2H, m), 7.90 (1H, dd, *J* = 9.2, 9.2 Hz), 8.03 (1H, dd, *J* = 9.2, 9.2 Hz), 8.11 (1H, dd, *J* = 9.2, 9.2 Hz), 8.29 (1H, s), 9.10 (1H, d, *J* = 10.0 Hz), 10.41 (1H, d, *J* = 9.6 Hz). *Anal*. Calcd for $C_{23}H_{16}N_2O_3$: C 74.99, H 4.38, N 7.60. Found: C 75.13, H 4.52, N 7.56.

***N*-(4-Methylphenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6e):** Orange needles (from EtOH). mp 252-254 ºC; IR (KBr, cm^{-1}): *v* 2223 (CN), 1655(C=O), 1624 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.05 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.61 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 2.47 (3H, s, CH_3), 7.37-7.38 (4H, m), 7.77 (1H, dd, *J* = 9.6, 9.6 Hz), 7.87-8.02 (2H, m), 8.14 (1H, s), 8.95 (1H, d, *J* = 10.8 Hz), 10.28 (1H, d, *J* = 9.6 Hz). *Anal*. Calcd for $C_{24}H_{18}N_2O_3$: C 75.38, H 4.74, N 7.33. Found: C 75.45, H 4.63, N 7.48.

***N*-(4-Methoxyphenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6f):** Orange needles (from MeOH). mp 248-250 ºC; IR (KBr, cm^{-1}): *v* 2220 (CN), 1652(C=O), 1629 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.10 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.70 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 3.89 (3H, s, OCH_3), 7.08 (2H, d, *J* = 7.6 Hz), 7.41 (2H, d, *J* = 7.9 Hz), 7.76 (1H, dd, *J* = 9.6, 9.6 Hz), 7.86-7.97 (2H, m), 8.12 (1H, s), 8.92 (1H, d, *J* = 10.5 Hz), 10.28 (1H, d, *J* = 9.0 Hz). *Anal*. Calcd for $C_{24}H_{18}N_2O_4$: C 72.35, H 4.55, N 7.03. Found: C 72.47, H 4.69, N 7.15.

***N*-(4-Chlorophenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6g):** Orange needles (from MeOH). mp > 300 ºC; IR (KBr, cm^{-1}): *v* 2228 (CN), 1655(C=O), 1635 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.11 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.73 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.46 (2H, d, *J* = 8.7 Hz), 7.57 (2H, d, *J* = 8.7 Hz), 7.79 (1H, dd, *J* = 9.3, 10.2 Hz), 7.92 (1H, dd, *J* = 9.3, 9.9 Hz), 8.01 (1H, dd, *J* = 9.0, 9.9 Hz), 8.12 (1H, s), 8.99 (1H, d, *J* = 10.5 Hz), 10.28 (1H, d, *J* = 9.3 Hz). *Anal*. Calcd for $C_{23}H_{15}ClN_2O_3$: C 68.58, H 3.75, N 6.95. Found: C 68.67, H 3.86, N 6.86.

***N*-(4-Fluorophenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6h):** Orange needles (from MeOH). mp 285-287 ºC; IR (KBr, cm^{-1}): *v* 2226 (CN), 1659(C=O), 1631 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.13 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.74 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 728-7.31 (2H, m), 7.48-7.53 (2H, m), 7.79 (1H, dd, *J* = 9.6, 9.9 Hz), 7.91 (1H, dd, *J* = 9.3, 9.9 Hz), 8.00 (1H, dd, *J* = 9.3, 9.9

Hz), 8.11 (1H, s), 8.96 (1H, d, *J* = 10.5 Hz), 10.29 (1H, d, *J* = 9.0 Hz). *Anal*. Calcd for $C_{23}H_{15}FN_2O_3$: C 71.50, H 3.91, N 7.25. Found: C 71.64, H 4.07, N 7.32.

***N*-(4-Methoxycarbonylphenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6i):** Orange needles (from MeOH). mp 270-271 ºC; IR (KBr, cm^{-1}): *v* 2220 (CN), 1673(C=O), 1654(C=O), 1633 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.05 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 1.45 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.61 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 4.44 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.58 (2H, d, *J* = 8.4 Hz), 7.82 (1H, dd, *J* = 9.6, 10.2 Hz), 7.98 (1H, dd, *J* = 9.0, 9.3 Hz), 8.07 (1H, dd, *J* = 9.0, 9.6 Hz), 8.17 (1H, s), 8.27 (2H, d, *J* = 8.4 Hz), 9.15 (1H, d, *J* = 10.5 Hz), 10.32 (1H, d, *J* = 9.3 Hz). *Anal*. Calcd for $C_{25}H_{18}N_2O_5$: C 70.42, H 4.25, N 6.57. Found: C 70.57, H 4.39, N 6.64.

***N*-(4-Nitrophenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6j):** Orange prisms (from MeOH). mp 297-298 ºC; IR (KBr, cm^{-1}): *v* 2229 (CN), 1659(C=O), 1636 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.12 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.75 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.71 (2H, d, *J* = 8.7 Hz), 7.79 (1H, dd, *J* = 9.6, 9.9 Hz), 7.98 (1H, dd, *J* = 9.3, 9.6 Hz), 8.07 (1H, dd, *J* = 9.6, 10.8 Hz), 8.16 (1H, s), 8.46 (2H, d, *J* = 8.7 Hz), 9.15 (1H, d, *J* = 10.5 Hz), 10.32 (1H, d, *J* = 9.3 Hz). *Anal*. Calcd for $C_{23}H_{15}N_3O_5$: C 66.83, H 3.66, N 10.16. Found: C 66.95, H 3.84, N 10.24.

***N*-(2-Methoxyphenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6k):** Orange needles (from MeOH). mp 261-263 ºC; IR (KBr, cm^{-1}): *v* 2221 (CN), 1652(C=O), 1627 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 1.20 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.82 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 3.98 (3H, s, OCH_3), 7.08 (2H, d, *J* = 7.6 Hz), 7.20-7.28 (2H, m), 7.48 (1H, d, *J* = 8.0 Hz), 7.60-7.64 (1H, m), 7.85 (1H, dd, *J* = 9.6, 9.6 Hz), 7.99-8.06 (2H, m), 8.16 (1H, s), 8.96 (1H, d, *J* = 10.0 Hz), 10.39 (1H, d, *J* = 9.2 Hz). *Anal*. Calcd for $C_{24}H_{18}N_2O_4$: C 72.35, H 4.55, N 7.03. Found: C 72.50, H 4.63, N 7.37.

***N*-(2-Fluorophenyl)-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6l):** Orange needles (from MeOH). mp 257-259 ºC; IR (KBr, cm^{-1}): *v* 2224 (CN), 1656(C=O), 1630 (C=O).^{1}H-NMR ($CDCl_3$): *δ* 1.23 (3H, t, *J* = 7.2 Hz, $OCH_2\underline{CH_3}$), 3.63 (2H, q, *J* = 7.2 Hz, $CO_2\underline{CH_2}CH_3$), 7.37-7.45 (1H, m), 7.47-7.52 (2H, m), 7.56-7.57 (1H, m), 7.92 (1H, dd, *J* = 9.2, 9.2 Hz), 8.07 (1H, dd, *J* = 9.2, 9.2 Hz), 8.13 (1H, dd, *J* = 9.2, 9.2 Hz), 8.18 (1H, s), 9.13 (1H, d, *J* = 10.0 Hz), 10.41 (1H, d, *J* = 10.4 Hz). *Anal*. Calcd for $C_{23}H_{15}FN_2O_3$: C 71.50, H 3.91, N 7.25. Found: C 71.68, H 4.12, N 7.41.

***N*-Cyclohexyl-3-cyano-10-ethoxycarbonylazuleno[2,1-*b*]pyridin-4(*1H*)-one (6m):** Orange needles (from EtOH). mp 263-265 ºC; IR (KBr, cm^{-1}): *v* 2215(CN), 1657 (C=O), 1634 (C=O). ^{1}H-NMR ($CDCl_3$): *δ* 0.95-1.02 (2H, m), 1.50-1.61 (5H, m), 1.77-1.83 (2H, m), 2.13 (2H, d, *J* = 13.6 Hz), 2.34 (2H, d, *J* = 11.2 Hz), 4.65-4.73 (3H, m), 7.88 (1H, dd, *J* = 9.2, 9.4 Hz), 7.99 (1H, dd, *J* = 9.2, 9.4 Hz), 8.08 (1H, dd, *J* = 9.2, 10.0 Hz), 8.29 (1H, s), 9.05 (1H, d, *J* = 10.4 Hz), 10.44 (1H, d, *J* = 9.2 Hz). *Anal*. Calcd for

$C_{23}H_{22}N_2O_3$: C 73.78, H 5.92, N 7.48. Found: C 73.84, H 5.86, N 7.61.

ACKNOWLEDGEMENT

This work was partially supported by the Key Laboratory of Synthesis & Application of Functional Compound of Liaoning Province (No. 2008T001), and Science and Technology Department of Liaoning Province (No. 2011220022).

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