Synthesis of 2-Aminofurans by Sequential [2 + 2] Cycloaddition–Nucleophilic Addition of 2-Propyn-1-ols with Tetracyanoethylene and Amine-induced Transformation to 6-Aminopentafulvenes

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Abstract: Synthesis of 2-aminofuran derivatives with azulene or *N,N*-dimethylanilino substituent was established by the formal [2 + 2] cycloaddition–retroelectrocyclization of 3-(1-azulenyl or *N,N*-dimethylanilino)-2-propyn-1-ols with tetracyanoethylene, followed by the intramolecular nucleophilic addition to the initially formed tetracyanobutadiene moiety of the internal hydroxyl group that come from 2-propyn-1-ol. The reaction proceeds under mild conditions with short reaction period. The products of the reaction are readily available with simple purification procedure. 2-Aminofuran derivatives obtained by this reaction were revealed to be convertible to 6-aminofulvene derivatives with the treatment of various amines. The structure of 2-aminofuran and 6-aminopentafulvene with *N,N*-dimethylanilino substituent was confirmed by single crystal X-ray structural analysis.
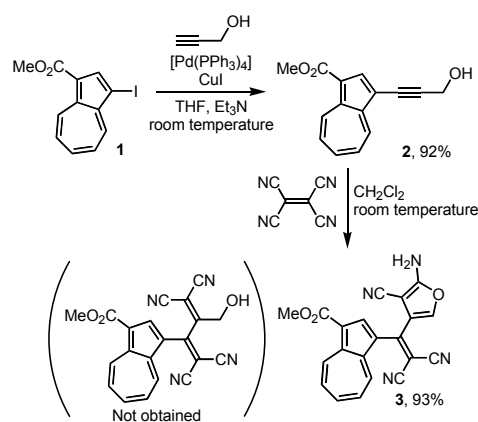
Introduction

Aminofuran shows various biological activities and is found in many pharmaceuticals.[1] Therefore, it is important to develop general and efficient methods to synthesize or modify such compounds. Classically, aminofurans have been prepared by the reaction of *α*-hydroxy-[2] and haloketones[3] with malononitrile under the basic conditions. As a modern procedure, transition metal-catalyzed reaction has been employed to construct the 2-aminofuran with various substituents.[4] More recently, Wang and co-workers have demonstrated the synthesis of 2-aminofurans by iodine-mediated sequential ring opening–cyclization domino reaction of 1-cyanocyclopropane in good yields.[5] Although these procedures have undoubtedly contributed to the development of 2-aminofuran synthesis, the requirement of expensive transition metal catalyst and/or difficulty in the preparation of the precursor remains in the preparation of the 2-aminofuran derivatives.

Azulene has attracted the interest of many researchers

owing to its unusual properties as well as its beautiful blue color.[6] Azulene derivatives have been extensively studied for their application to organic electronics,[7] medicinal chemistry,[8] bioimaging,[9] stimuli responsive materials[10] and so forth. Therefore, various efficient and facile synthetic methods for azulene derivatives have been developed and reported in literatures.[11]

Formal [2 + 2] cycloaddition–retroelectrocyclization (CA–RE) of electron-rich alkynes with tetracyanoethylene (TCNE) is one of the efficient procedures to construct the donor–acceptor systems, i.e., tetracyanobutadiene derivatives (TCBDs).[12] In exploring the reaction for the synthesis of new TCBDs, we have encountered unexpectedly formation of 2-aminofuran derivatives in excellent yields (e.g., **3**; 93%) by the [2 + 2] CA–RE of 3-(1-azulenyl)-2-propyn-1-ols (e.g., **2**) with TCNE in CH_2Cl_2 (Scheme 1). Although the presumed 1-azulenylTCBD derivatives could not be obtained at all in the reaction, we realized that the finding should become an efficient and convenient method for the preparation of azulene-substituted 2-aminofuran derivatives, because of the ready availability of the starting materials. Moreover, we also encountered the unexpected formation of 6-aminopentafulvene derivatives during the investigation of the reactivity of 2-aminofuran derivatives with various amines.

Herein, we describe a novel synthetic procedure for the 2-aminofuran derivatives with azulene function by the [2 + 2] CA–RE of the corresponding 3-(1-azulenyl)-2-propyn-1-ols with TCNE, as well as an efficient amine-induced transformation of the 2-aminofuran derivatives to 6-aminopentafulvenes. These transformations should enable to synthesize the functionalized 2-aminofuran and 6-aminopentafulvene derivatives with facility and efficiently.
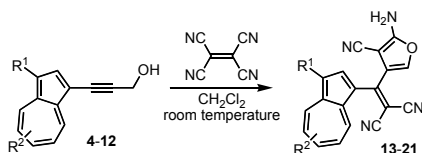
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Scheme 1. Synthesis of 2-aminofuran derivative **3** with azulene substituent.

Results and Discussion

Inspired by the results described above, we have examined the scope of the reaction of 3-(1-azulenyl)-2-propyn-1-ols **4−12** possessing several functional groups on the azulene ring with TCNE (Table 1). The reaction of the alkynes **4−12** with TCNE (2 equiv. vs alkyne) was carried out in CH_2Cl_2 at room temperature under an aerobic condition. In general, the products were obtained in good yields by the reaction within 1 hour. The

reaction of **4** afforded the corresponding 2-aminofuran **13** in 77% yield, after the chromatographic purification on silica gel (entry 1). Likewise, the other alkynes **5−12** readily reacted with TCNE at room temperature to give the desired 2-aminofurans **14−21** in good yields (entries 2−9). We could conclude the reaction is little affected by the functional groups on the azulene ring about the reaction outcome, since all reaction produced the products in good yields.

In 2014, Zhang *et al.* reported an efficient synthesis of furan derivatives by the dehydrogenative cyclization reaction of 2-(1-alkynyl)-2-alken-1-ones utilizing TCNE as a dienophile, but their approach required elevated temperature (i.e., 60 °C), long reaction period (6−12 hours) and expensive gold catalyst.[13] An advantageous feature of our methodology is that the reaction does not require any expensive transition metal catalyst to afford highly functionalized 2-aminofuran derivatives. Moreover, the reaction proceeds under milder conditions within a short time. Thus, the present method would become one of the efficient methodologies for the synthesis of 2-aminofuran derivatives.

Presumed reaction mechanism is illustrated in Scheme 2. The reaction commences with the formal [2 + 2] cycloaddition of the alkyne **2** with TCNE to form strained cyclobutene derivative **A**, followed by ring-opening by retroelectrocyclization of the cyclobutene ring to give the TCBD derivative **B**.[14,15] Intramolecular nucleophilic addition of the hydroxyl group to the cyano moiety in TCBD **B** results in the dihydrofuran **C**, which then exhibits tautomerization to form a furan ring with cyano and amine functions in **3**. Since the TCBD **B** is not obtained in the reaction, intramolecular nucleophilic addition to form **C** should be a faster process than that of the formal [2 + 2] CA–RE to form TCBD **B**.

Table 1. Synthesis of 2-aminofurans **13−21** by the reaction of 3-(1-azulenyl)-2-propyn-1-ols **4−12** with TCNE

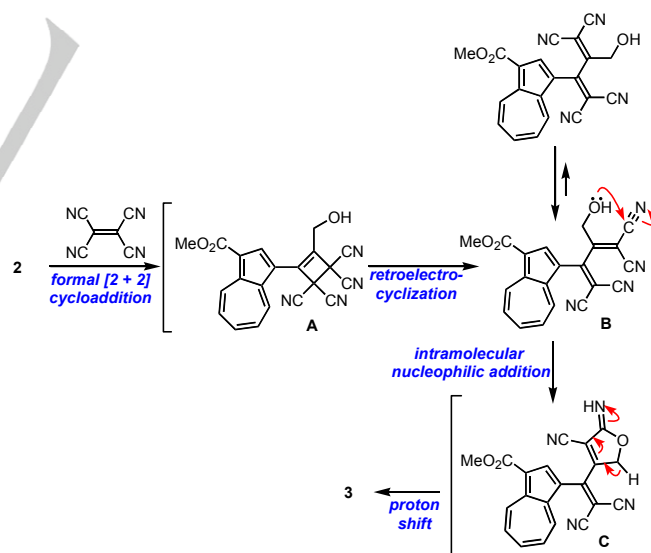| Entry	Azulene	Substrate	Reaction time [min]	Product, Yield [%][a]
1	MeO_2C, iPr	**4**	60	**13**, 77
2	MeO_2C, iPr	**5**	60	**14**, 79
3	MeO_2C, Me, iPr	**6**	60	**15**, 87
4	MeOC	**7**	60	**16**, 60
5	NC	**8**	60	**17**, 70
6	Cl	**9**	30	**18**, 99
7	Ph, i-Pr	**10**	5	**19**, 71
8	Me, iPr	**11**	10	**20**, 61
9	Et, iPr	**12**	10	**21**, 77

[a] Isolated yield.

Scheme 2. Presumed reaction mechanism for the reaction of **2** with TCNE.

6-Aminopentafulvene derivatives have attracted the interest of many research groups, because of their importance for the precursor of natural products,[16] metallocenes[17] and novel π-eletron compounds including fulvenes,[18] porphyrins[19] and azulene derivatives.[20] 6-Aminopentafulvenes have usually been prepared from cyclopentadienide ion with the

corresponding amides or their analogs,[21] but there is no report for the conversion to 6-aminopentafulvenes from the 2-aminofuran precursor.

During the investigation of the reactivity of 2-aminofuran 13, we found the formation of 6-aminofulvene derivatives with an azulene substituent 22a−29a, 26b and 27b by the treatment with a large excess of amines under mild conditions. As shown in Table 2, products were obtained generally in good yields. When diisopropylamine was used in the reaction, however, 24a was obtained in 16% yield (entry 3). The lower yield of 24a should reflect the steric hindrance of diisopropylamine that prevent the nucleophilic addition of the amine. To use pyrrolidine in the reaction at room temperature, 27b was obtained in 64% yield as a sole product (entry 6). In contrast, the reaction with pyrrolidine at 0 °C afforded 27a in 95% yield (entry 7). Similar to the reaction with diisopropylamine, the reaction with sterically bulky *tert*-butylamine resulted in lower yield compared to that of the other amines (entry 9).

Although some synthetic methods of 6-aminopentafulvenes have been reported in the literature,[22] our procedure is the first synthesis of 6-aminopentafulvene derivatives from 2-aminofurans by amine-induced transformation. Moreover, in the viewpoint of azulene chemistry, compounds 22a−29a, 26b and 27b are the first examples of 6-aminopentafulvene derivatives with an azulene substituent.
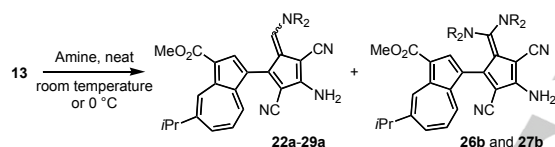
**Table 2.** Amine-induced synthesis of 6-aminofulvenes 22a−29a,[23] 26b and 27b from 2-aminofuran 13.

Entry	Amine	RR'N	Reaction time [h]	Product, Yield [%][a]
1	diethylamine	Et₂N	0.5	22a, 70
2	dipropylamine	nPr₂N	0.5	23a, 63
3	diisopropylamine	iPr₂N	7	24a, 16
4	morpholine	O⟍N	0.5	25a, 98
5	piperidine	N	0.5	26a,45 and 26b, 17
6	pyrrolidine	N	1	27b, 64
7[b]	pyrrolidine	N	1	27a, 95
8	*n*-butylamine	nBuNH	1	28a, 62
9	*tert*-butylamine	tBuNH	1	29a, 41

[a] Isolated yield. [b] Reaction was performed at 0 ºC.

The detailed reaction mechanism for the formation of 6-aminopentafulvenes is not clear at the current stage, but presumed reaction mechanism is illustrated in Scheme 3. In the

first step, the amine attacks the furan ring of compound 13 by 1,4-conjugate addition mode to produce D, followed by the ring-opening reaction of the furan moiety and the proton shift to give F via E. The first conjugate addition of amine is supported by DFT calculations, since the LUMO coefficient is located at the 5-position of the furan ring (Figure S179). The alkene carbon bearing two cyano groups attacks to the amido carbonyl carbon to form G. Eventually, one of the cyano groups in G was transferred by nucleophilic attack of the neighboring alkoxide oxygen, followed by the elimination of cyanic acid under the basic condition to generate 6-aminopentafulvene M via L.[24]

We have examined the further reaction of 6-aminopentafulvene 25a with pyrrolidine. As a result, the reaction afforded the amine exchanged product 27a (26%) on the fulvene carbon at 6-position, along with 6,6-diaminofulvene 27b (28%) (Scheme 4). Since the reaction did not afford 27b with high product yield under the reaction conditions, the formation of 6,6-diaminofulvene might involve two competing pathways. As a pathway, the formation of diaminofulvene K might be explained by the nucleophilic attack of another amine to the iminium ion moiety of the intermediate G for the aminofulvene formation, followed by the elimination of hydrogen cyanide and water through H, I and J (path A). Another pathway is that the addition of the amine to 6-position of aminofulvene M, followed by the oxidation with air via N (path B). Since the yield of 27b by the reaction of 25a with pyrrolidine was relatively low, the 6-aminopentafulvene might not be an efficient precursor for the diaminofulvene formation.
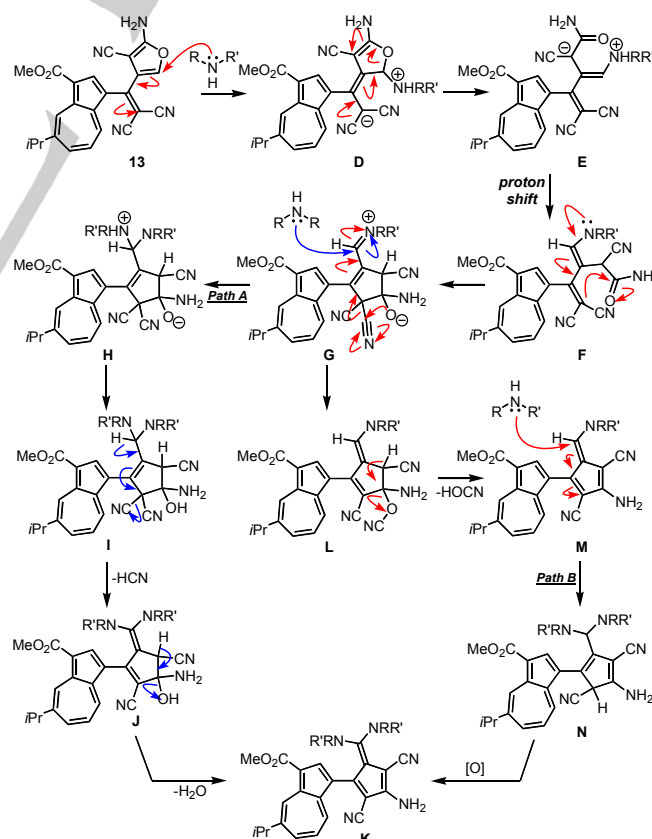

Scheme 3. Presumed reaction mechanism for the reaction of 2-aminofuran 13 with amines.
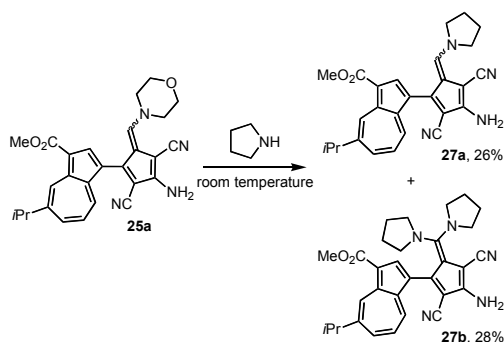
Scheme 4. The reaction of **25a** with pyrrolidine.

Although the UV/Vis spectrum of 2-aminofuran derivatives **3** and **13**−**21** showed a strong absorption band in the visible region (420−487 nm), absorption maxima of these compounds varied with each other depending on the substituents on the azulene ring. For instance, the longest absorption band of **13** (λ_{max} = 437 nm) showed slight bathochromic shift compared with that of **3** (λ_{max} = 424 nm). Further red-shift for the longest absorption band was observed in **20** (λ_{max} = 487 nm, Figure 1). The DFT calculations at the B3LYP/6-31G** level[25] revealed that the strong absorption band of **3**, **13** and **20** could be assignable to intramolecular charge transfer between the HOMOs, which located on both azulene and 2-aminofuran moieties, and the LUMOs, which mainly located on azulene and dicyanovinyl groups (Figures S179−S181). Therefore, the strong absorption band of **3**, **13** and **20** in the visible region could be attributed to overlap of the transitions from azulene and 2-aminofuran to azulene and dicyanovinyl moieties. Calculated HOMO–LUMO gap of **13** (3.25 eV) and **20** (3.02 eV) was lower than that of **3** (3.30 eV). Therefore, alkyl substituents such as methyl and isopropyl groups on **13** and **20** should contribute to decrease the HOMO–LUMO gap owing to increase the HOMO level by electron-donating inductive effect.
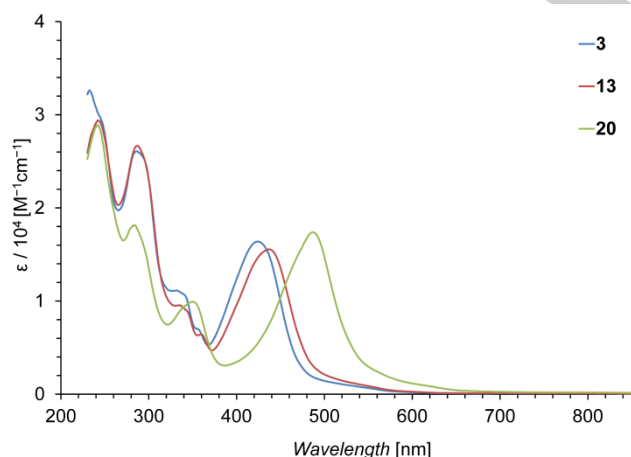

Figure 1. The UV/Vis spectra of **3** (blue line), **13** (red line) and **20** (light green line) in CH_2Cl_2.

Similarly to the results on azulene derivatives, alkyne **30** with *N,N*-dimethylanilino substituent reacted with TCNE at room temperature to give 2-aminofuran **31** in 85% yield. The reaction of **31** with pyrrolidine afforded 6-aminopentafulvene **32** in 63% yield. The structure of **31** and **32** was confirmed by single crystal

X-ray structural analysis since the suitable single crystals for X-ray structural analysis were obtained by slow evaporation from $CHCl_3$ (Figures 1 and 2). To investigate the quinoid character of *N,N*-dimethylanilino (DMA) moiety of **31** and **32**, the δ_r was calculated by the equation as shown in below (bond lengths *A*, *A'*, *B*, *B'*, *C* and *C'* are shown in Figures 2 and 3).[26]

$$\delta_r = \{[(A + A')−(B + B')]/2 + [(C + C')−(B + B')]/2\}/2$$

Calculated from the X-ray crystal structure, 2-aminofuran **31** exhibited δ_r = 0.047, which indicates the quinoid character of the DMA moiety owing to the resonance effect between DMA group and dicyanovinyl moiety as shown in Scheme 4. In contrast, the δ_r value of the DMA ring in 6-aminopentafulvene **32** was relatively low (δ_r = 0.019). Previously, Diederich *et al*. reported the δ_r value of two DMA rings connected with 6,6-dicyanopentafulvene. In that study, they revealed that the DMA ring with high planarity to the 6,6-dicyanopentafulvene moiety displayed a very large δ_r value (δ_r = 0.065).[27] On the other hand, the DMA ring with less effective conjugation showed a low δ_r value (δ_r = 0.030). The δ_r value of **32** reflects a small contribution of the quinoid form **32'** relative to that of **31** due to the low planarity between the DMA and the 6-aminopentafulvene moieties (Scheme 5).[28] Furthermore, since the electron-rich 6-aminofulvene acts against the quinoid structure by its push-pull effect, lower δ_r value of **32** rather than that of the 6,6-dicyanopentafulvene derivative reflects the both features.
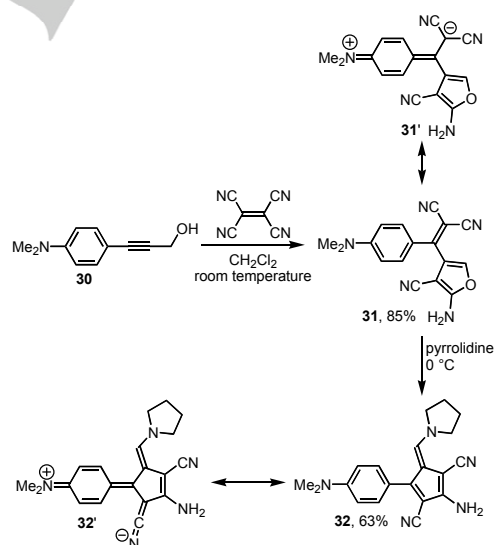

Scheme 5. Synthesis of 2-aminofuran **31** and 6-aminopentafulvene **32** with *N,N*-dimethylanilino substituent.
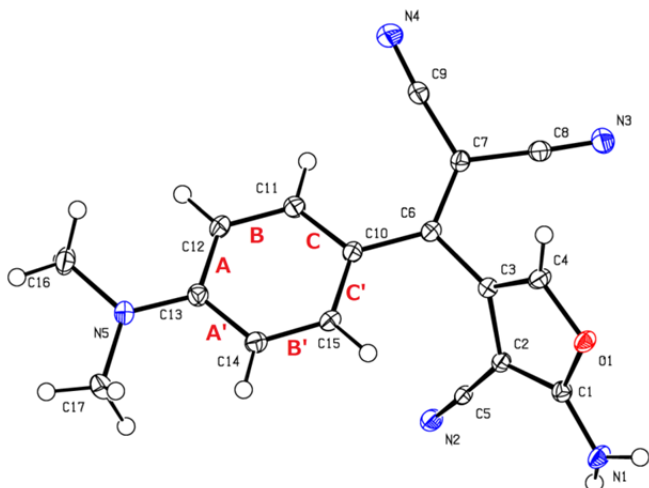
Figure 2. Molecular structure of **31**; solvent is omitted for clarity. Ellipsoids are drawn at 50% probability. [29] triclinic, $a = 8.74184(18)$ Å, $b = 10.5270(2)$ Å, $c = 10.8782(2)$ Å, $\alpha = 81.4148(19)°$, $\beta = 78.9101(18)°$, $\gamma = 77.7054(19)°$, $V = 953.70(3)$ Å^3, $Z = 2$, $D_{calcd} = 1.472$ g/cm^3, μ(Mo-Kα) = 4.985 cm^{-1}, R_1 [$I > 2\sigma(I)$] = 0.0302, wR_2 [all data] = 0.0808; C10−C11 1.4094(16), C10−C15 1.4165(15), C11−C12 1.3676(16), C12−C13 1.4219(15), C13−C14 1.4157(16), C14−C15 1.3707(16).
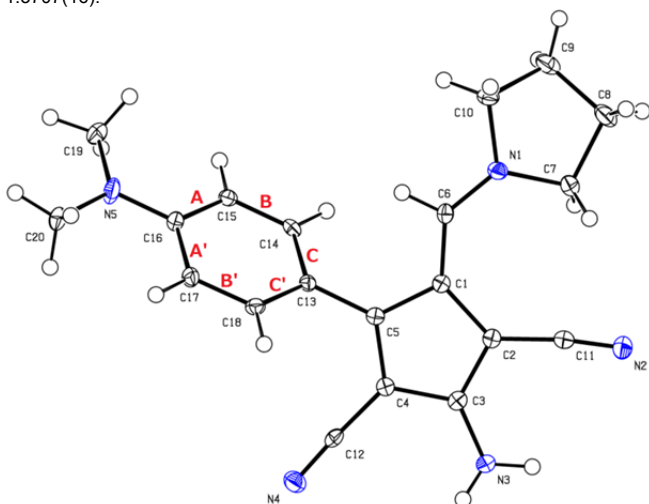

Figure 3. Molecular structure of **32**. Ellipsoids are drawn at 50% probability.[29] orthorhombic, $a = 9.7534(3)$ Å, $b = 10.1308(3)$ Å, $c = 17.7754(6)$, $V = 1756.38(10)$ Å^3, $Z = 4$, $D_{calcd} = 1.253$ g/cm^3, μ(Mo-Kα) = 0.777 cm^{-1}, R_1 [$I > 2\sigma(I)$] = 0.0421, wR_2 [all data] = 0.0888; C13−C14 1.401(3), C13−C18 1.395(3), C14−C15 1.379(3), C15−C16 1.403(3), C16−C17 1.412(3), C17−C18 1.388(3).

The UV/Vis spectra of aminofulvenes **22a**–**29a**, **26b** and **27b** with 1-azulenyl substituent showed weak absorptions at around 560−600 nm, although aminofulvene **32** with N,N-dimethylanilino substituent did not display absorption band in this region (Figure 4). Thus, the longest wavelength absorptions of **22a**–**29a**, **26b** and **27b** should arise from the transition from the azulene part. Aminofulvenes **22a**–**29a**, **26b**, **27b** and **32** also exhibited the broad and strong absorption band at around 400 nm.

To elucidate the origin of these absorption bands, molecular orbital calculations were performed on **27a**, **27b** and **32** as model compounds, using B3LYP/6-31G** density

functional theory. Thus, the longest wavelength absorption bands of **27a** (λ_{max} = 556 nm) and **27b** (λ_{max} = 600 nm) should be concluded as the transition from the HOMO located on both azulene and aminofulvene moieties to the LUMO located on the 1-azulenyl group (Figures S183 and S184). Thus, there are some contributions of intramolecular charge transfer (ICT) character from aminofulvene to azulene moieties in these bands, although 1-azulenyl group usually behaves as an electron-donating group. These results suggest that aminofulvene has higher electron-donating nature rather than that of 1-azulenyl group. The broad and strong absorption bands of **27a** (λ_{max} = 375 nm and 436 sh nm) and **27b** (λ_{max} = 421 nm and 450 sh nm) could be assigned to the overlap of some transitions originated from the HOMOs largely located on aminofulvene moiety to the LUMOs largely located on aminofulvene and azulene rings. Thus, the broad absorption band of **27a** and **27b** could be arisen from the overlap of ICT from aminofulvene to azulene moieties and the π−π* transition of the aminofulvene part. Calculated HOMO–LUMO gap of **27b** (2.41 eV) was lower than that of **27a** (2.70 eV). Thus, the amino moieties at 6-position of fulvene should contribute to decrease the HOMO–LUMO gap, due to increase the HOMO level by its strong electron-donating nature.

Different from the results of **27a** and **27b**, the calculations revealed that the longest absorption band of **32** in the visible region was caused by the transition from HOMO, HOMO−1 and HOMO−2 to LUMO, which could be assigned to overlap of the π−π* transition of aminofulvene itself and ICT from N,N-dimethylanilino substituent to aminofulvene moiety (Figure S185). These results imply that 6-aminofulvene behaves as an electron acceptor in this case, which is consistent with that the N,N-dimethylanilino substituent has higher electron-donating ability compared to that of 1-azulenyl group[30] and 6-aminofulvene moiety.
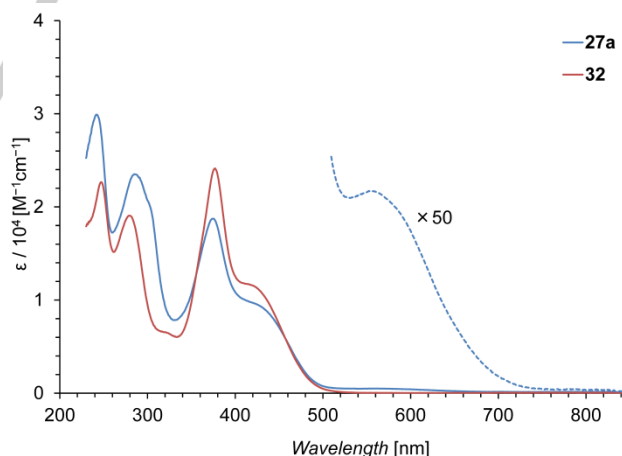
Figure 4. The UV/Vis spectra of **27a** (blue line) and **32** (red line) in CH$_2$Cl$_2$.

Conclusions

In conclusion, we described a novel synthetic method for 2-aminofuran and 6-aminopentafulvene derivatives. 2-Aminofurans **3**, **13**–**21** and **32** were synthesized in a one-step procedure consisting of formal [2 + 2] CA–RE of the corresponding alkynes **2**, **4**–**12** and **31** with TCNE, followed by

intramolecular nucleophilic addition of the hydroxyl group to the initially formed TCBD moiety. Since the reaction proceeds under milder conditions with a short reaction time without expensive transition metal catalyst, our synthetic method has potentials to be one of the efficient procedures for the synthesis of 2-aminofuran derivatives. We also established an efficient synthesis of 6-aminopentafulvene derivatives **22a**−**29a**, **26b** and **27b** and **32** by amine-induced transformation of 2-aminofurans **13** and **31**. The procedure is the first example for the preparation of 6-aminopentafulvenes from 2-aminofurans by the amine-induced reaction.

Experimental Section

Melting points were determined with a Yanagimoto MPS3 micro melting apparatus and are uncorrected. High-resolution mass spectra were obtained with a Bruker Daltonics APEX III instrument (dithranol as a matrix substance and/or CF_3CO_2Ag as an auxiliary agent). IR and UV/Vis spectra were measured with JASCO FT/IR-4100 and Shimadzu UV-2550 spectrophotometer. ^1H and ^{13}C NMR spectra were recorded in $CDCl_3$ with a JEOL ECA500 at 500 MHz and 125 MHz, respectively. Since 2-aminofuran derivatives **3** and **13**−**21** showed low solibility toward $CDCl_3$, NMR spectra of these compounds were measured in acetone-d_6. In the cases of soluble compounds, ^1H NMR data in $CDCl_3$ were also appeared in experimental details. Experimental details of alkynes **2** and **4**−**12** are shown in the Supporting Information.

Compound 3: TCNE (257 mg, 2.01 mmol) was added to a solution of **2** (246 mg, 1.02 mmol) in CH_2Cl_2 (7 mL). The resulting mixture was stirred at room temperature for 1 h under an Ar atmosphere. Precipitated crystals were collected by filtration and recrystallized from toluene to give **3** (348 mg, 93%) as an orange solid. M.p. 281−284 °C (decomp.); IR (AT-IR): v_{max} = 3372 (w), 3323 (w), 3274 (w), 3218 (w), 3182 (w), 3140 (w), 3002 (w), 2951 (w), 2222 (m), 1687 (s), 1652 (s), 1598 (m), 1551 (m), 1540 (w), 1517 (m), 1500 (s), 1444 (s), 1433 (s), 1409 (s), 1379 (m), 1328 (w), 1304 (w), 1269 (w), 1248 (m), 1219 (s), 1175 (m), 1157 (w), 1125 (m), 1095 (w), 1054 (m), 989 (w), 969 (w), 955 (w), 901 (w), 878 (m), 855 (w), 798 (m), 782 (m), 771 (w), 748 (m), 720 (w), 705 (w), 684 (w), 672 (w), 655 (w) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 233 (4.51), 246 sh (4.47), 287 (4.42), 296 sh (4.40), 338 sh (4.03), 357 sh (3.84), 424 (4.21), 526 sh (2.99) nm; ^1H NMR (500 MHz, acetone-d_6): δ_H = 9.85 (d, 1H, J = 10.0 Hz, H$_4$), 8.66 (d, 1H, J = 10.0 Hz, H$_8$), 8.62 (s, 1H, H$_2$), 8.24 (t, 1H, J = 10.0 Hz, H$_6$), 8.02 (t, 1H, J = 10.0 Hz, H$_5$), 7.92 (t, 1H, J = 10.0 Hz, H$_7$), 7.84 (s, 1H, furan-H), 7.06 (s, 2H, NH$_2$), 3.91 (s, 3H, CO$_2$Me) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ_C = 165.39, 164.46, 156.25, 144.75, 143.08, 142.56, 142.44, 139.78, 138.85, 136.75, 132.01, 131.12, 123.78, 121.30, 117.59, 114.98, 114.58, 112.33, 78.39, 67.75, 50.88 ppm; HRMS (MALDI-TOF): calcd for $C_{21}H_{12}N_4O_3$ + Ag$^+$ [M + Ag]$^+$ 474.9955; found: 474.9965.

Compound 13: TCNE (1.10 g, 8.66 mmol) was added to a solution of **4** (1.21 g, 4.28 mmol) in CH_2Cl_2 (20 mL). The resulting mixture was stirred at room temperature for 1 h under an Ar

atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with CH_2Cl_2/AcOEt (10 : 1) to give **13** (1.35 g, 77%) as an orange solid. M.p. 270−273 °C (decomp.); IR (AT-IR): v_{max} = 3370 (w), 3322 (w), 3273 (w), 3218 (w), 3182 (w), 3136 (w), 2974 (w), 2224 (m), 1686 (s), 1651 (s), 1599 (m), 1550 (m), 1526 (m), 1500 (m), 1440 (s), 1422 (m), 1411 (s), 1374 (m), 1323 (w), 1271 (w), 1247 (w), 1219 (s), 1178 (m), 1157 (w), 1127 (m), 1090 (w), 1059 (m), 1007 (m), 988 (w), 966 (w), 932 (w), 896 (m), 882 (w), 857 (w), 810 (m), 797 (m), 778 (m), 767 (w), 735 (w), 691 (m), 667 (w), 656 (w) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 242 (4.47), 286 (4.43), 297 sh (4.39), 335 sh (3.98), 360 (3.81), 426 sh (4.17), 437 (4.19), 535 sh (3.07) nm; ^1H NMR (500 MHz, acetone-d_6): δ_H = 10.00 (d, 1H, J = 1.5 Hz, H$_4$), 8.62 (s, 1H, H$_2$), 8.57 (d, 1H, J = 10.0 Hz, H$_8$), 8.24 (d, 1H, J = 10.0 Hz, H$_6$), 7.92 (t, 1H, J = 10.0 Hz, H$_7$), 7.84 (s, 1H, furan-H), 7.07 (s, 2H, NH$_2$), 3.94 (s, 3H, CO$_2$Me), 3.38 (sept, 1H, J = 7.0 Hz, iPr), 1.47 (d, 6H, J = 7.0 Hz, iPr) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ_C = 166.07, 165.38, 156.81, 154.70, 145.63, 144.16, 143.31, 142.45, 139.94, 138.21, 137.48, 131.84, 124.61, 121.12, 117.62, 115.96, 115.52, 113.20, 78.26, 68.69, 51.65, 39.89, 24.76 ppm; HRMS (MALDI-TOF): calcd for $C_{24}H_{18}N_4O_3$ + Ag$^+$ [M + Ag]$^+$ 517.0424; found: 517.0438.

Compound 14: TCNE (223 mg, 1.74 mmol) was added to a solution of **5** (233 mg, 0.825 mmol) in CH_2Cl_2 (8 mL). The resulting mixture was stirred at room temperature for 1 h under an Ar atmosphere. Precipitated crystals were collected by filtration and recrystallized from $CHCl_3$ to give **14** (268 mg, 79%) as an orange solid. M.p. 262−265 °C (decomp.); IR (AT-IR): v_{max} = 3369 (w), 3325 (w), 3272 (w), 3220 (w), 3184 (w), 3141 (w), 2963 (w), 2225 (m), 1687 (s), 1650 (s), 1599 (m), 1585 (w), 1547 (m), 1523 (m), 1505 (m), 1442 (s), 1420 (m), 1400 (m), 1377 (m), 1327 (w), 1312 (w), 1270 (w), 1246 (w), 1218 (s), 1156 (w), 1125 (m), 1085 (w), 1059 (m), 1036 (w), 1006 (w), 985 (w), 917 (w), 904 (w), 893 (w), 878 (w), 854 (m), 800 (w), 778 (w), 756 (w), 732 (w), 711 (w), 689 (w), 673 (w) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 234 (4.54), 248 sh (4.49), 294 sh (4.49), 302 (4.52), 345 (4.12), 430 (4.28), 529 sh (3.08) nm; ^1H NMR (500 MHz, CDCl$_3$): δ_H = 9.78 (d, 1H, J = 10.5 Hz, H$_4$), 8.40 (s, 1H, H$_2$), 8.31 (d, 1H, J = 10.5 Hz, H$_8$), 7.81 (d, 1H, J = 10.5 Hz, H$_5$), 7.70 (d, 1H, J = 10.5 Hz, H$_7$), 7.55 (s, 1H, furan-H), 4.98 (s, 2H, NH$_2$), 3.95 (s, 3H, CO$_2$Me), 3.24 (sept, 1H, J = 6.9 Hz, iPr), 1.42 (d, 6H, J = 6.9 Hz, iPr) ppm; ^1H NMR (500 MHz, acetone-d_6): δ_H = 9.76 (d, 1H, J = 10.5 Hz, H$_4$), 8.56 (d, 1H, J = 10.5 Hz, H$_8$), 8.52 (s, 1H, H$_2$), 7.98 (dd, 1H, J = 10.5, 1.5 Hz, H$_5$), 7.89 (dd, 1H, J = 10.5, 1.5 Hz, H$_7$), 7.80 (s, 1H, furan-H), 7.05 (br. s, 2H, NH$_2$), 3.90 (s, 3H, CO$_2$Me), 3.31 (sept, 1H, J = 7.0 Hz, iPr), 1.40 (d, 6H, J = 7.0 Hz, iPr) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ_C = 165.76, 165.29, 164.52, 156.25, 143.60, 142.04, 141.33, 139.40, 138.46, 136.66, 131.39, 130.48, 123.86, 121.10, 117.48, 115.10, 114.69, 112.39, 77.74, 67.88, 50.79, 39.67, 23.53 ppm; HRMS (MALDI-TOF): calcd for $C_{24}H_{18}N_4O_3$ + Ag$^+$ [M + Ag]$^+$ 517.0424; found: 517.0418.

Compound 15: TCNE (124 mg, 0.968 mmol) was added to a solution of **6** (133 mg, 0.449 mmol) in CH_2Cl_2 (5 mL). The resulting mixture was stirred at room temperature for 1 h under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with AcOEt to give **15** (165 mg, 87%) as an orange

solid. M.p. 126−129 °C (decomp.); IR (AT-IR): v_{max} = 3325 (w), 3260 (w), 3211 (w), 3162 (w), 2958 (w), 2218 (m), 1677 (m), 1646 (s), 1592 (m), 1554 (m), 1527 (m), 1493 (m), 1434 (s), 1381 (m), 1335 (w), 1309 (w), 1285 (w), 1225 (s), 1200 (m), 1178 (w), 1144 (m), 1123 (m), 1088 (m), 1050 (w), 1026 (w), 977 (w), 924 (w), 857 (w), 846 (w), 815 (w), 796 (w), 784 (m), 757 (w), 734 (w), 710 (w), 686 (m), 676 (w), 665 (w) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 244 (4.55), 297 (4.59), 351 (4.01), 367 sh (3.89), 439 (4.03), 531 sh (3.00) nm; ^{1}H NMR (500 MHz, CDCl$_3$): 9.80 (d, 1H, J = 1.4 Hz, H$_4$), 8.02 (d, 1H, J = 10.0 Hz, H$_8$), 7.85 (d, 1H, J = 10.0 Hz, H$_6$), 7.69 (s, 1H, furan-H), 7.59 (t, 1H, J = 10.0 Hz, H$_7$), 4.98 (s, 2H, NH$_2$), 3.99 (s, 3H, CO$_2$Me), 3.26 (t, 1H, J = 6.9 Hz, iPr), 2.70 (s, 3H), 1.44 (d, 3H, J = 6.9 Hz, iPr), 1.42 (d, 3H, J = 6.9 Hz, iPr) ppm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 9.80 (s, 1H, H$_4$), 8.35 (d, 1H, J = 10.0 Hz, H$_8$), 8.02 (d, 1H, J = 10.0 Hz, H$_6$), 7.90 (s, 1H, furan-H), 7.73 (t, 1H, J = 10.0 Hz, H$_7$), 7.03 (br. s, 2H, NH$_2$), 3.95 (s, 3H, CO$_2$Me), 3.29 (sept, 1H, J = 7.0 Hz, iPr), 2.71 (s, 3H, Me), 1.41 (s, 6H, J = 7.0 Hz, iPr) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 165.73, 165.48, 157.33, 153.65, 152.30, 143.72, 141.32, 139.40, 137.39, 136.64, 134.55, 130.25, 124.38, 121.68, 116.14, 114.26, 114.15, 111.92, 81.69, 67.27, 50.56, 39.16, 24.02, 23.94, 15.97 ppm; HRMS (MALDI-TOF): calcd for C$_{25}$H$_{20}$N$_4$O$_3$ + Ag$^+$ [M + Ag]$^+$ 531.0581; found: 531.0570.

Compound 16: TCNE (63 mg, 0.49 mmol) was added to a solution of **7** (56 mg, 0.25 mmol) in CH$_2$Cl$_2$ (5 mL). The resulting mixture was stirred at room temperature for 1 h under an Ar atmosphere. After removing the precipitate by filtration, the filtrate was concentrated under reduced pressure. The residue was purified by column chromatography on silica gel with CH$_2$Cl$_2$/AcOEt (2 : 1) to give **16** (53 mg, 60%) as an orange solid. M.p. 226−229 °C (decomp.); IR (AT-IR): v_{max} = 3439 (w), 3308 (w), 3200 (w), 3160 (w), 2221 (m), 1669 (m), 1625 (m), 1603 (m), 1542 (m), 1506 (m), 1435 (s), 1371 (s), 1305 (w), 1268 (w), 1243 (w), 1213 (m), 1177 (w), 1152 (w), 1121 (w), 1088 (w), 1050 (w), 983 (m), 911 (w), 875 (m), 851 (w), 809 (w), 791 (w), 754 (s), 724 (w), 706 (w), 683 (w), 668 (w) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 236 (4.46), 255 (4.40), 284 (4.34), 301 (4.32), 337 sh (4.01), 369 (3.93), 431 (4.18), 532 sh (2.97) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ$_H$ = 10.11 (d, 1H, J = 10.0 Hz, H$_4$), 8.50 (s, 1H, H$_2$), 8.35 (d, 1H, J = 10.0 Hz, H$_8$), 8.09 (t, 1H, J = 10.0 Hz, H$_6$), 7.93 (t, 1H, J = 10.0 Hz, H$_5$), 7.77 (t, 1H, J = 10.0 Hz, H$_7$), 7.63 (s, 1H, furan-H), 5.02 (s, 2H, NH$_2$), 2.73 (s, 3H, COMe) ppm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 10.02 (d, 1H, J = 10.0 Hz, H$_4$), 8.79 (s, 1H, H$_2$), 8.67 (d, 1H, J = 10.0 Hz, H$_8$), 8.24 (t, 1H, J = 10.0 Hz, H$_6$), 8.03 (t, 1H, J = 10.0 Hz, H$_5$), 7.95 (t, 1H, J = 10.0 Hz, H$_7$), 7.81 (s, 1H, furan-H), 7.06 (s, 2H, NH$_2$), 2.67 (s, 3H, COMe) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 194.64, 165.38, 156.36, 144.19, 144.12, 142.87, 142.65, 141.08, 138.93, 136.89, 133.12, 131.52, 125.49, 123.84, 121.38, 115.09, 114.62, 112.44, 78.05, 67.80 ppm, one signal is overlapped with solvent signals; HRMS (MALDI-TOF): calcd for C$_{21}$H$_{12}$N$_4$O$_2$ + Ag$^+$ [M + Ag]$^+$ 459.0006; found: 459.0006.

Compound 17: TCNE (133 mg, 1.04 mmol) was added to a solution of **8** (107 mg, 0.516 mmol) in CH$_2$Cl$_2$ (7 mL). The resulting mixture was stirred at room temperature for 1 h under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography

on silica gel with CH$_2$Cl$_2$/AcOEt (5 : 1) to give **17** (121 mg, 70%) as an orange solid. M.p. 237−239 °C; IR (AT-IR): v_{max} = 3373 (w), 3327 (w), 3268 (w), 3212 (w), 3170 (w), 3084 (w), 2221 (s), 1669 (s), 1632 (w), 1596 (m), 1577 (w), 1560 (m), 1531 (m), 1513 (s), 1447 (s), 1427 (s), 1390 (w), 1364 (s), 1301 (m), 1263 (w), 1253 (w), 1232 (w), 1171 (w), 1129 (m), 1101 (w), 1053 (w), 994 (w), 966 (w), 913 (w), 882 (w), 856 (w), 792 (w), 753 (s), 719 (w), 700 (w), 640 (w), 624 (w), 612 (w) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 244 sh (4.43), 283 (4.44), 296 sh (4.35), 337 sh (4.01), 420 (4.17), 535 sh (2.94) nm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 8.89 (d, 1H, J = 10.0 Hz, H$_4$), 8.73 (d, 1H, J = 10.0 Hz, H$_8$), 8.58 (s, 1H, H$_2$), 8.34 (t, 1H, J = 10.0 Hz, H$_6$), 8.08 (t, 1H, J = 10.0 Hz, H$_5$), 8.00 (t, 1H, J = 10.0 Hz, H$_7$), 7.87 (s, 1H, furan-H), 7.08 (s, 2H, NH$_2$) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 165.43, 155.55, 146.47, 143.38, 142.98, 140.40, 139.67, 138.78, 137.07, 131.72, 131.67, 123.54, 122.20, 115.46, 114.70, 114.35, 112.30, 98.81, 79.39, 67.56 ppm; HRMS (MALDI-TOF): calcd for C$_{20}$H$_9$N$_5$O + Ag$^+$ [M + Ag]$^+$ 441.9853; found: 441.9866.

Compound 18: TCNE (129 mg, 1.01 mmol) was added to a solution of **9** (108 mg, 0.498 mmol) in CH$_2$Cl$_2$ (5 mL). The resulting mixture was stirred at room temperature for 30 min under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with CH$_2$Cl$_2$/AcOEt (10 : 1) to give **18** (170 mg, 99%) as a dark red solid. M.p. 226−229 °C (decomp.); IR (AT-IR): v_{max} = 3405 (w), 3328 (w), 3252 (w), 3200 (w), 3161 (w), 2870 (w), 2216 (m), 1647 (s), 1588 (m), 1577 (m), 1560 (m), 1539 (m), 1508 (m), 1489 (m), 1443 (s), 1400 (m), 1378 (m), 1359 (s), 1313 (w), 1288 (m), 1227 (w), 1195 (w), 1157 (w), 1112 (m), 1081 (w), 1039 (m), 1023 (w), 972 (m), 917 (m), 876 (m), 853 (m), 775 (m), 746 (m), 730 (m), 696 (m), 681 (m), 663 (m) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 236 (4.52), 280 (4.41), 344 (4.03), 456 (4.21) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ$_H$ = 8.64 (d, 1H, J = 10.0 Hz, H$_8$), 8.25 (d, 1H, J = 10.0 Hz, H$_4$), 7.98–7.94 (m, 2H, H$_2$ and furan-H), 7.67 (t, 1H, J = 10.0 Hz, H$_6$), 7.59 (t, 1H, J = 10.0 Hz, H$_7$), 7.55 (s, 1H, H$_5$), 4.96 (s, 2H, NH$_2$) ppm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 8.67 (d, 1H, J = 10.0 Hz, H$_8$), 8.52 (d, 1H, J = 10.0 Hz, H$_4$), 8.20 (s, 1H, H$_2$), 8.11 (t, 1H, J = 10.0 Hz, H$_6$), 7.80 (m, 2H, H$_7$ and furan-H), 7.73 (t, 1H, J = 10.0 Hz, H$_5$), 7.05 (s, 2H, NH$_2$) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 165.31, 165.28, 154.94, 142.23, 139.63, 138.45, 137.40, 136.76, 136.68, 129.00, 128.98, 123.87, 120.15, 118.29, 115.32, 114.78, 112.46, 77.16, 68.00 ppm; HRMS (FAB-MS): calcd for C$_{19}$H$_9$ClN$_4$O$^+$ [M]$^+$ 344.0460; found: 344.0463.

Compound 19: TCNE (86 mg, 0.67 mmol) was added to a solution of **10** (94 mg, 0.31 mmol) in CH$_2$Cl$_2$ (5 mL). The resulting mixture was stirred at room temperature for 5 min under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with CH$_2$Cl$_2$/AcOEt (5 : 1) to give **19** (95 mg, 71%) as a red solid. M.p. 209−211 °C; IR (AT-IR): v_{max} = 3387 (w), 3322 (w), 3269 (w), 3214 (w), 3144 (w), 2962 (w), 2219 (m), 1651 (s), 1596 (w), 1561 (w), 1506 (m), 1488 (m), 1454 (m), 1434 (s), 1366 (m), 1314 (w), 1242 (w), 1193 (w), 1168 (w), 1115 (w), 1084 (w), 1039 (w), 997 (w), 930 (w), 875 (w), 854 (w), 814 (w), 794 (w), 772 (m), 746 (w), 698 (m), 632 (m) cm^{-1}; UV/Vis (MeCN): λ_{max} (log ε) = 251 (4.43),

288 sh (4.26), 353 (4.06), 457 sh (3.98), 483 (4.11), 591 (2.95) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ$_H$ = 8.58 (d, 1H, J = 10.0 Hz, H$_4$), 8.26 (d, 1H, J = 1.5 Hz, H$_8$), 8.16 (s, 1H, H$_2$), 7.82 (d, 1H, J = 10.0 Hz, H$_6$), 7.58−7.48 (m, 6H, H$_5$, furan-H and o,m-Ph), 7.40 (t, 1H, J = 7.5 Hz, p-Ph), 4.93 (s, 2H, NH$_2$), 3.15 (sept, 1H, J = 6.9 Hz, iPr), 1.34 (d, 6H, J = 6.9 Hz, iPr) ppm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 8.65 (d, 1H, J = 10.0 Hz, H$_4$), 8.42 (d, 1H, J = 1.5 Hz, H$_8$), 8.36 (s, 1H, H$_2$), 7.98 (d, 1H, J = 10.0 Hz, H$_6$), 7.74 (s, 1H, furan-H), 7.66–7.61 (m, 3H, H$_5$ and o-Ph), 7.51 (t, 2H, J = 7.5 Hz, m-Ph), 7.39 (t, 1H, J = 7.5 Hz, p-Ph), 6.87 (s, 2H, NH$_2$), 3.20 (sept, 1H, J = 7.0 Hz, iPr), 1.32 (d, 6H, J = 7.0 Hz, iPr) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 165.24, 155.27, 149.92, 142.35, 141.13, 140.66, 139.83, 136.93, 136.24, 135.97, 135.82, 132.13, 129.58, 129.08, 128.83, 127.19, 124.51, 120.87, 115.97, 115.16, 112.32, 75.02, 68.95, 38.73, 23.67 ppm; HRMS (MALDI-TOF): calcd for C$_{28}$H$_{20}$N$_4$O + Ag$^+$ [M + Ag]$^+$ 535.0683; found: 535.0672.

Compound 20: TCNE (210 mg, 1.64 mmol) was added to a solution of **11** (258 mg, 1.08 mmol) in CH$_2$Cl$_2$ (5 mL). The resulting mixture was stirred at room temperature for 10 min under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with CH$_2$Cl$_2$/AcOEt (10 : 1) to give **20** (240 mg, 61%) as a red solid. M.p. 256−258 °C; IR (AT-IR): ν$_{max}$ = 3377 (w), 3326 (w), 3265 (w), 3212 (w), 3182 (w), 2962 (w), 2930 (w), 2865 (w), 2217 (s), 1657 (s), 1598 (w), 1577 (w), 1561 (w), 1537 (w), 1494 (s), 1462 (m), 1412 (s), 1368 (s), 1310 (w), 1259 (w), 1248 (w), 1205 (w), 1173 (w), 1140 (w), 1117 (w), 1084 (w), 1071 (w), 1046 (m), 1012 (w), 981 (w), 947 (w), 926 (w), 917 (m), 876 (w), 854 (w), 800 (w), 759 (m), 748 (w), 736 (w), 718 (w), 690 (m), 678 (w), 668 (w), 656 (w) cm^{-1}; UV/Vis (MeCN): λ$_{max}$ (log ε) = 242 (4.46), 284 (4.26), 350 (4.00), 460 sh (4.11), 487 (4.24) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ$_H$ = 8.30 (d, 1H, J = 10.0 Hz, H$_4$), 8.14 (s, 1H, H$_8$), 8.02 (s, 1H, H$_2$), 7.77 (d, 1H, J = 10.0 Hz, H$_6$), 7.48–7.52 (m, 2H, H$_5$ and furan-H), 4.91 (s, 2H, NH$_2$), 3.09 (sept, 1H, J = 7.0 Hz, iPr), 2.61 (s, 3H, Me), 1.29 (d, 6H, J = 6.9 Hz, iPr) ppm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 8.44 (d, 1H, J = 10.0 Hz, H$_4$), 8.29 (s, 1H, H$_8$), 8.12 (s, 1H, H$_2$), 7.92 (d, 1H, J = 10.0 Hz, H$_6$), 7.70 (s, 1H, furan-H), 7.60 (t, 1H, J = 10.0 Hz, H$_5$), 7.04 (s, 2H, NH$_2$), 3.14 (t, 1H, J = 6.9 Hz, iPr), 2.60 (s, 3H, Me), 1.26 (d, 6H, J = 6.9 Hz, iPr) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 152.20, 152.17, 143.61, 139.58, 135.63, 132.79, 132.38, 132.06, 128.85, 128.60, 127.93, 122.48, 122.05, 119.63, 116.13, 113.10, 112.48, 110.06, 78.51, 74.93, 51.03, 39.03, 29.35 ppm; HRMS (FAB-MS): calcd for C$_{23}$H$_{18}$N$_4$O$^+$ [M]$^+$ 366.1476; found: 366.1469.

Compound 21: TCNE (265 mg, 2.07 mmol) was added to a solution of **12** (343 mg, 1.36 mmol) in CH$_2$Cl$_2$ (7 mL). The resulting mixture was stirred at room temperature for 10 min under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with CH$_2$Cl$_2$/AcOEt (10 : 1) to give **21** (400 mg, 77%) as a red solid. M.p. 255−257 °C; IR (AT-IR): ν$_{max}$ = 3424 (w), 3332 (w), 3276 (w), 3218 (w), 3173 (w), 3132 (w), 2964 (w), 2930 (w), 2870 (w), 2218 (s), 1653 (s), 1593 (m), 1550 (m), 1485 (s), 1462 (s), 1433 (s), 1410 (s), 1380 (s), 1299 (m), 1254 (w), 1235 (w), 1176 (w), 1117 (m), 1092 (m), 1073 (w),

1038 (w), 1011 (w), 982 (w), 950 (w), 911 (m), 880 (m), 858 (w), 803 (m), 781 (w), 758 (w), 744 (w), 723 (m), 695 (m), 683 (w), 670 (w), 661 (w) cm^{-1}; UV/Vis (MeCN): λ$_{max}$ (log ε) = 242 (4.48), 283 (4.27), 350 (4.00), 460 sh (4.12), 487 (4.26) nm; ^{1}H NMR (500 MHz, acetone-d_6): δ$_H$ = 8.50 (d, 1H, J = 10.0 Hz, H$_4$), 8.30 (d, 1H, J = 1.0 Hz, H$_8$), 8.17 (s, 1H, H$_2$), 7.93 (d, 1H, J = 10.0 Hz, H$_6$), 7.70 (s, 1H, furan-H), 7.60 (t, 1H, J = 10.0 Hz, H$_5$), 7.05 (s, 2H, NH$_2$), 3.15 (sept, 1H, J = 6.9 Hz, iPr), 3.05 (q, 2H, J = 7.5 Hz, Et), 1.35 (t, 3H, J = 7.5 Hz, Et), 1.27 (d, 6H, J = 6.9 Hz, iPr) ppm; ^{13}C NMR (125 MHz, acetone-d_6): δ$_C$ = 152.20, 143.72, 139.59, 134.94, 132.84, 132.07, 131.21, 128.94, 128.62, 127.64, 127.34, 122.52, 119.63, 116.27, 113.11, 112.48, 110.04, 78.52, 74.92, 51.02, 39.04, 35.79, 31.52 ppm; HRMS (FAB-MS): calcd for C$_{24}$H$_{20}$N$_4$O$^+$ [M]$^+$ 380.1627; found: 380.1628.

Compound 22a: A solution of **13** (246 mg, 0.599 mmol) in Et$_2$NH (8 mL) was stirred at room temperature for 30 min. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (10 : 1) as an eluent to afford **22a** (186 mg, 70%) as a brown solid. M.p. 218−220 °C; IR (AT-IR): ν$_{max}$ = 3328 (w), 3225 (w), 2962 (w), 2202 (w), 2176 (m), 1687 (s), 1615 (s), 1542 (m), 1524 (s), 1479 (s), 1448 (s), 1414 (m), 1380 (m), 1364 (m), 1346 (s), 1278 (w), 1220 (s), 1170 (m), 1147 (m), 1080 (m), 1036 (w), 998 (w), 954 (w), 926 (w), 901 (w), 807 (m), 792 (w), 777 (m), 736 (w), 691 (w), 681 (w), 670 (w), 658 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ$_{max}$ = 240 (4.44), 285 (4.33), 304 sh (4.27), 372 (4.24), 435 sh (3.90), 555 (2.63), 602 (2.53) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ$_H$ = 9.83 (d, 1H, J = 1.5 Hz, H$_4$), 8.30 (d, 1H, J = 10.0 Hz, H$_8$), 8.20 (s, 1H, H$_2$), 7.83 (d, 1H, J = 10.0 Hz, H$_6$), 7.48 (t, 1H, J = 10.0 Hz, H$_7$), 6.99 (s, 1H, H$_{6'}$ of pentafulvene), 4.66 (s, 2H, NH$_2$), 3.97 (s, 3H, CO$_2$Me), 3.63 (br. s, 4H, Et$_2$N), 3.26 (sept, 1H, J = 7.0 Hz, iPr), 1.45 (d, 6H, J = 7.0 Hz, iPr), 1.31 (br. s, 6H, Et$_2$N) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ$_C$ = 165.72, 156.79, 150.49, 150.39, 146.40, 142.20, 142.14, 139.61, 138.77, 136.68, 127.60, 119.84, 119.66, 116.31, 115.25, 110.65, 92.32, 71.57, 51.21, 49.85, 39.31, 24.72, 14.33 ppm, one signal is overlapped with the other signal; HRMS (MALDI-TOF): calcd for C$_{27}$H$_{28}$N$_4$O$_2$$^+$ [M]$^+$ 440.2207; found: 440.2211.

Compound 23a: A solution of **13** (106 mg, 0.258 mmol) in n-Pr$_2$NH (5 mL) was stirred at room temperature for 30 min. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (20 : 1) as an eluent to afford **23a** (76 mg, 63%) as a brown solid. M.p. 226−228 °C; IR (AT-IR): ν$_{max}$ = 3388 (w), 3338 (w), 3236 (w), 2968 (w), 2937 (w), 2875 (w), 2199 (w), 2174 (w), 1685 (m), 1651 (w), 1606 (s), 1525 (s), 1485 (m), 1469 (m), 1455 (m), 1415 (m), 1380 (m), 1353 (m), 1337 (s), 1212 (s), 1172 (m), 1146 (m), 1100 (m), 1073 (m), 1045 (w), 950 (m), 936 (w), 899 (w), 875 (w), 809 (m), 776 (s), 746 (m), 707 (w), 695 (m), 684 (m), 661 (m), 650 (s) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ$_{max}$ = 243 (4.59), 285 (4.48), 303 sh (4.42), 374 (4.39), 436 (4.06), 552 (2.87), 608 sh (2.73) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ$_H$ = 9.83 (d, 1H, J = 1.5 Hz, H$_4$), 8.30 (d, 1H, J = 10.0 Hz, H$_8$), 8.18 (s, 1H, H$_2$), 7.83 (d, 1H, J = 10.0 Hz, H$_6$), 7.48 (t, 1H, J = 10.0 Hz, H$_7$), 6.98 (s, 1H, H$_{6'}$ of pentafulvene), 4.65 (s, 2H, NH$_2$), 3.97 (s, 3H, CO$_2$Me), 3.48 (br. s, 4H, nPr), 3.26 (sept, 1H, J = 7.0 Hz, iPr), 1.72 (br. s, 4H, nPr), 1.45 (d, 6H, J = 7.0 Hz, iPr), 0.97 (br. s, 6H, nPr) ppm;

^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.76, 156.72, 151.41, 150.42, 142.26, 142.18, 139.62, 138.77, 136.77, 127.64, 119.90, 119.76, 116.37, 115.22, 110.69, 92.20, 71.57, 58.02, 51.19, 39.30, 24.72, 21.83, 10.95 ppm, two signals are overlapped with the other signals; HRMS (MALDI-TOF): calcd for C$_{29}$H$_{32}$N$_4$O$_2^+$ [M]$^+$ 468.2520; found: 468.2509.

Compound 24a: A solution of **13** (202 mg, 0.492 mmol) in *i*Pr$_2$NH (5 mL) was stirred at room temperature for 7 h. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$ as an eluent to afford **24a** (38 mg, 16%) as a brown solid. M.p. 249−252 °C; IR (AT-IR): ν_{max} = 3395 (w), 3234 (w), 2970 (w), 2202 (w), 2183 (m), 1688 (m), 1607 (m), 1538 (m), 1488 (m), 1456 (m), 1416 (m), 1387 (m), 1350 (m), 1319 (m), 1213 (s), 1175 (m), 1133 (m), 1046 (m), 1009 (m), 954 (m), 895 (m), 878 (w), 807 (m), 779 (m), 747 (w), 730 (w), 714 (w), 689 (m), 676 (w), 664 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 243 (4.68), 286 (4.59), 306 sh (4.49), 374 (4.46), 440 sh (4.17), 559 (2.87), 601 sh (2.79) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.84 (s, 1H, H$_4$), 8.34 (d, 1H, J = 10.0 Hz, H$_8$), 8.18 (s, 1H, H$_2$), 7.83 (d, 1H, J = 10.0 Hz, H$_6$), 7.49 (t, 1H, J = 10.0 Hz, H$_7$), 7.12 (s, 1H, H$_{6'}$ of pentafulvene), 5.05 (br. s, 1H, *i*Pr), 4.64 (s, 2H, NH$_2$), 3.95 (s, 3H, CO$_2$Me), 3.26 (sept, 1H, J = 7.0 Hz, *i*Pr), 1.45 (d, 6H, J = 7.0 Hz, *i*Pr), 1.30 (br. s, 6H, *i*Pr) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.75, 156.55, 150.41, 147.75, 145.58, 142.56, 142.27, 141.99, 139.64, 138.77, 136.99, 127.63, 119.92, 119.36, 116.64, 115.11, 110.52, 91.25, 71.87, 53.90, 51.17, 39.29, 24.71, 21.99 ppm, one signal is overlapped with the other signal; HRMS (MALDI-TOF): calcd for C$_{29}$H$_{32}$N$_4$O$_2^+$ [M]$^+$ 468.2520; found: 468.2512.

Compound 25a: A solution of **13** (207 mg, 0.504 mmol) in morpholine (5 mL) was stirred at room temperature for 30 min. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (5 : 1) as an eluent to afford **25a** (225 mg, 98%) as a brown solid. M.p. 180−182 °C; IR (AT-IR): ν_{max} = 3342 (w), 3227 (w), 2973 (w), 2188 (w), 1733 (w), 1716 (w), 1684 (m), 1615 (s), 1542 (m), 1525 (m), 1489 (m), 1457 (m), 1418 (m), 1388 (m), 1347 (m), 1266 (w), 1216 (s), 1171 (m), 1116 (m), 1070 (w), 1027 (m), 954 (w), 903 (w), 875 (w), 840 (w), 803 (w), 776 (m), 741 (w), 719 (w), 694 (w), 683 (m), 671 (m), 657 (m) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 241 (4.92), 285 (4.82), 305 sh (4.73), 378 (4.71), 447 sh (4.38), 563 sh (3.17), 601 (3.06) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.83 (d, 1H, J = 1.5 Hz, H$_4$), 8.31 (d, 1H, J = 10.0 Hz, H$_8$), 8.20 (s, 1H, H$_2$), 7.84 (d, 1H, J = 10.0 Hz, H$_6$), 7.51 (t, 1H, J = 10.0 Hz, H$_7$), 6.91 (s, 1H, H$_{6'}$ of pentafulvene), 4.72 (s, 2H, NH$_2$), 3.97 (s, 3H, CO$_2$Me), 3.82 (br. s, 8H, morpholine-H), 3.27 (sept, 1H, J = 7.0 Hz, *i*Pr), 1.45 (d, 6H, J = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.69, 156.60, 150.65, 149.63, 146.89, 142.23, 142.11, 142.07, 139.81, 138.95, 136.70, 127.76, 119.74, 119.40, 116.03, 115.41, 111.59, 93.27, 71.24, 66.89, 53.36, 51.25, 39.31, 24.70 ppm; HRMS (MALDI-TOF): calcd for C$_{27}$H$_{26}$N$_4$O$_3^+$ [M]$^+$ 454.1999; found: 454.2001.

Reaction of 13 with piperidine: A solution of **13** (215 mg, 0.524 mmol) in piperidine (5 mL) was stirred at room temperature for 30 min. After the reaction, amine was removed under reduced

pressure. The crude product was purified by silica gel column chromatography with AcOEt as an eluent to afford **26a** (107 mg, 45%) as a brown solid and **26b** (47 mg, 17%) as a brown solid.

26a: M.p. 260−262 °C; IR (AT-IR): ν_{max} = 3389 (w), 3322 (w), 3229 (w), 2957 (w), 2935 (w), 2869 (w), 2206 (m), 2178 (m), 1685 (s), 1543 (m), 1524 (s), 1480 (m), 1454 (m), 1414 (m), 1378 (m), 1347 (s), 1339 (s), 1322 (m), 1276 (w), 1262 (w), 1252 (w), 1170 (m), 1120 (w), 1090 (w), 1073 (w), 1019 (m), 996 (w), 964 (m), 931 (w), 903 (w), 887 (w), 853 (w), 811 (w), 777 (m), 717 (w), 689 (w), 676 (w), 665 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 243 (4.67), 286 (4.58), 306 sh (4.48), 376 (4.46), 441 sh (4.15), 580 (2.85) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.82 (s, 1H, H$_4$), 8.31 (d, 1H, J = 10.0 Hz, H$_8$), 8.20 (s, 1H, H$_2$), 7.82 (d, 1H, J = 10.0 Hz, H$_6$), 7.49 (t, 1H, J = 10.0 Hz, H$_7$), 6.96 (s, 1H, H$_{6'}$ of pentafulvene), 4.62 (s, 2H, NH$_2$), 3.97 (s, 3H, CO$_2$Me), 3.72 (br. s, 4H, piperidine-H), 3.26 (t, 1H, J = 7.0 Hz, *i*Pr), 1.75 (s, 6H, piperidine-H), 1.45 (d, 6H, J = 7.0 Hz, *i*Pr) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.77, 156.02, 150.54, 150.39, 145.53, 142.18, 139.62, 138.81, 136.77, 127.60, 120.00, 119.68, 116.43, 115.33, 110.92, 92.08, 71.83, 54.76, 51.19, 39.31, 26.69, 24.71, 23.53 ppm, two signals are overlapped with the other signals; HRMS (MALDI-TOF): calcd for C$_{28}$H$_{28}$N$_4$O$_2^+$ [M]$^+$ 452.2207; found: 452.2217.

26b: M.p. 289−292 °C; IR (AT-IR): ν_{max} = 3351 (w), 3229 (w), 2973 (w), 2937 (w), 2860 (w), 2176 (m), 1687 (w), 1621 (m), 1504 (s), 1476 (m), 1449 (s), 1415 (m), 1344 (m), 1325 (m), 1254 (w), 1218 (s), 1167 (m), 1132 (m), 1082 (w), 1025 (m), 960 (w), 912 (w), 874 (w), 855 (w), 806 (w), 776 (m), 740 (w), 714 (w), 699 (w), 688 (w), 678 (w), 661 (m), 641 (w), 625 (m), 610 (m) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 250 (4.54), 285 (4.56), 293 sh (4.52), 328 sh (4.04), 366 (4.09), 432 (3.95), 594 (2.65) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.70 (d, 1H, J = 1.5 Hz, H$_4$), 8.34 (d, 1H, J = 10.0 Hz, H$_8$), 8.03 (s, 1H, H$_2$), 7.73 (d, 1H, J = 10.0 Hz, H$_6$), 7.36 (t, 1H, J = 10.0 Hz, H$_7$), 4.18 (s, 2H, NH$_2$), 3.96 (s, 3H, CO$_2$Me), 3.52 (br. s, 2H, piperidine-H), 3.40 (br. s, 2H, piperidine-H), 3.22 (sept, J = 7.0 Hz, 1H, *i*Pr), 2.88 (s, 2H, piperidine-H), 1.63–1.27 (m, 20H, *i*Pr and piperidine-H) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.90, 165.81, 151.17, 149.31, 141.61, 140.53, 139.85, 139.13, 138.33, 136.29, 130.71, 126.58, 123.40, 120.08, 118.61, 115.03, 105.59, 85.80, 76.33, 52.58, 52.36, 51.19, 39.18, 25.89, 25.14, 24.67, 23.89 ppm, one signal of aliphatic region is overlapped with the other signal; HRMS (MALDI-TOF): calcd for C$_{33}$H$_{37}$N$_5$O$_2^+$ [M]$^+$ 535.2942; found: 535.2939.

Compound 27a: A solution of **13** (103 mg, 0.251 mmol) in pyrrolidine (5 mL) was stirred at 0 °C for 1 h under an Ar atmosphere. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt as an eluent to afford **27a** (105 mg, 95%) as a brown solid. M.p. 271−273 °C; IR (AT-IR): ν_{max} = 3395 (w), 3325 (w), 3230 (w), 2957 (w), 2201 (m), 2176 (m), 1687 (s), 1614 (s), 1542 (m), 1524 (m), 1481 (m), 1454 (m), 1413 (m), 1378 (m), 1363 (s), 1334 (s), 1311 (m), 1221 (s), 1169 (m), 1130 (m), 1104 (m), 1070 (m), 1033 (m), 904 (m), 875 (m), 847 (w), 805 (w), 778 (m), 749 (w), 720 (w), 687 (m), 668 (m), 653 (m) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 242 (4.48), 285 (4.37), 304 sh (4.29), 375 (4.27), 436 sh (3.95), 556 (2.64), 600 sh (2.54) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.82 (s, 1H, H$_4$), 8.32 (d, 1H, J = 10.0 Hz, H$_8$), 8.18 (s, 1H, H$_2$), 7.83 (d, 1H, J = 10.0 Hz, H$_6$),

7.50 (t, 1H, J = 10.0 Hz, H$_7$), 7.17 (s, 1H, H$_{6'}$ of pentafulvene), 4.65 (s, 2H, NH$_2$), 4.07 (s, 2H, pyrrolidine-H), 3.96 (s, 3H), 3.60 (s, 1H, pyrrolidine-H), 3.51 (s, 1H, pyrrolidine-H), 3.25 (sept, 1H, J = 6.9 Hz, iPr), 2.14 (s, 2H, pyrrolidine-H), 1.97 (s, 2H, pyrrolidine-H), 1.44 (d, 6H, J = 6.9 Hz, iPr) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.78, 156.47, 150.37, 147.92, 145.40, 142.09, 142.05, 141.91, 139.71, 138.69, 136.64, 127.70, 120.22, 119.66, 116.46, 114.95, 112.12, 92.36, 71.39, 56.05, 52.52, 51.29, 39.29, 26.57, 24.76, 24.41 ppm; HRMS (MALDI-TOF): calcd for C$_{27}$H$_{26}$N$_4$O$_2$$^+$ [M]$^+$, 438.2050; found: 438.2044.

Compound 27b: A solution of **13** (97 mg, 0.236 mmol) in pyrrolidine (5 mL) was stirred at room temperature for 1 h. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (5 : 1) as an eluent to afford **27b** (76 mg, 64%) as a brown solid. M.p. 275−277 °C; IR (AT-IR): v_{max} = 3345 (w), 2958 (w), 2172 (m), 1683 (m), 1622 (m), 1542 (m), 1506 (m), 1475 (s), 1453 (s), 1411 (m), 1361 (w), 1330 (m), 1217 (s), 1170 (m), 1127 (m), 1077 (w), 1042 (w), 964 (w), 908 (w), 876 (m), 857 (w), 807 (m), 779 (m), 728 (w), 694 (m), 683 (m), 668 (m), 656 (m), 634 (m), 616 (m), 604 (m) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 252 (4.70), 287 (4.68), 328 sh (4.19), 363 (4.09), 421 (4.05), 450 sh (3.97), 600 (2.76) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.65 (d, 1H, J = 1.5 Hz, H$_4$), 8.45 (d, 1H, J = 10.0 Hz, H$_8$), 7.99 (s, 1H, H$_2$), 7.72 (d, 1H, J = 10.0 Hz, H$_6$), 7.37 (t, 1H, J = 10.0 Hz, H$_7$), 4.12 (br. s, 2H, NH$_2$), 3.95 (s, 3H, CO$_2$Me), 3.76–3.71 (m, 2H, pyrrolidine-H), 3.39–3.16 (m, 7H, iPr and pyrrolidine-H), 1.97–1.89 (m, 2H, pyrrolidine-H), 1.83–1.75 (m, 2H, pyrrolidine-H), 1.55–1.32 (m, 10H, iPr and pyrrolidine-H) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.88, 161.16, 150.43, 149.17, 141.42, 139.86, 139.47, 139.16, 138.15, 136.50, 126.56, 125.50, 123.62, 119.84, 119.33, 114.94, 105.52, 82.75, 74.11, 52.24, 51.68, 51.18, 39.15, 25.80, 24.65, 24.26 ppm; HRMS (MALDI-TOF): calcd for C$_{31}$H$_{33}$N$_5$O$_2$$^+$ [M]$^+$ 507.2629; found: 507.2625.

Compound 28a: A solution of **13** (210 mg, 0.511 mmol) in nBuNH$_2$ (5 mL) was stirred at room temperature for 1 h. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (10 : 1) as an eluent to afford **28a** (139 mg, 62%) as a brown solid. M.p. 225−226 °C; IR (AT-IR): v_{max} = 3388 (w), 3342 (w), 3217 (w), 2960 (w), 2872 (w), 2194 (w), 2170 (m), 1686 (m), 1627 (s), 1539 (s), 1483 (m), 1442 (m), 1415 (m), 1377 (m), 1334 (m), 1289 (m), 1213 (s), 1167 (m), 1108 (m), 1070 (m), 1045 (m), 994 (m), 932 (w), 886 (w), 807 (w), 776 (m), 740 (w), 705 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 240 (4.70), 285 (4.59), 304 sh (4.50), 377 (4.50), 428 (4.19), 560 sh (2.93), 599 sh (2.82) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.82 (d, 1H, J = 1.5 Hz, H$_4$), 8.39 (d, 1H, J = 10.0 Hz, H$_8$), 8.22 (s, 1H, H$_2$), 7.85 (d, 1H, J = 10.0 Hz, H$_6$), 7.51 (t, 1H, J = 10.0 Hz, H$_7$), 6.98 (s, 1H, H$_{6'}$ of pentafulvene), 6.90 (br. s, 1H, NH), 4.71 (s, 2H, NH$_2$), 3.97 (s, 3H, CO$_2$Me), 3.35−3.23 (m, 3H, nBu and iPr), 1.58 (q, 2H, J = 7.0 Hz, nBu),1.44 (d, 6H, J = 7.0 Hz, iPr), 1.37 (sext, 2H, J = 7.0 Hz, nBu), 0.92 (t, 3H, J = 7.0 Hz, nBu) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.75, 154.41, 150.55, 149.68, 144.33, 142.23, 141.78, 141.39, 139.88, 138.77, 136.65, 127.76, 119.85, 118.85, 116.34, 115.21, 112.16, 92.76, 69.55, 51.30, 50.10, 39.27, 32.61, 24.73,

19.57, 13.62 ppm; HRMS (MALDI-TOF): calcd for C$_{27}$H$_{28}$N$_4$O$_2$ + H$^+$ [M + H]$^+$ 441.2285; found: 441.2279.

Compound 29a: A solution of **13** (209 mg, 0.509 mmol) in tBuNH$_2$ (5 mL) was stirred at room temperature for 1 h. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (10 : 1) as an eluent to afford **29a** (92 mg, 41%) as a brown solid. M.p. 234−236 °C; IR (AT-IR): v_{max} = 3380 (w), 3346 (w), 3244 (w), 2967 (w), 2202 (w), 2174 (w), 1686 (m), 1615 (m), 1550 (m), 1483 (w), 1444 (m), 1415 (m), 1377 (w), 1305 (w), 1207 (s), 1177 (s), 1116 (w), 1071 (w), 1047 (w), 966 (w), 935 (w), 894 (w), 812 (w), 776 (w), 741 (w), 696 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} = 242 (4.66), 284 (4.54), 305 sh (4.44), 377 (4.46), 430 (4.15), 556 sh (2.86), 612 sh (2.70) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 9.83 (s, 1H, H$_4$), 8.40 (d, 1H, J = 10.0 Hz, H$_8$), 8.24 (s, 1H, H$_2$), 7.84 (d, 1H, J = 10.0 Hz, H$_6$), 7.50 (t, 1H, J = 10.0 Hz, H$_7$), 7.14 (m, 2H, H$_{6'}$ of pentafulvene and NH), 4.71 (s, 2H, NH$_2$), 3.26 (sept, 1H, J = 7.0 Hz, iPr), 3.96 (s, 3H, CO$_2$Me), 1.44 (d, 6H, J = 7.0 Hz, iPr), 1.30 (s, 9H, tBu) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 165.75, 154.51, 150.49, 145.65, 143.97, 142.27, 141.67, 141.35, 139.86, 138.75, 136.60, 127.60, 119.92, 118.96, 116.46, 115.33, 111.84, 92.36, 69.41, 54.86, 51.32, 39.24, 29.81, 29.42, 24.71 ppm; HRMS (MALDI-TOF): calcd for C$_{27}$H$_{28}$N$_4$O$_2$ + H$^+$ [M + H]$^+$ 441.2285; found: 441.2288.

Compound 31: TCNE (256 mg, 2.00 mmol) was added to a solution of **30**[31] (176 mg, 1.00 mmol) in CH$_2$Cl$_2$ (10 mL). The resulting mixture was stirred at room temperature for 30 min under an Ar atmosphere. The solvent was removed under reduced pressure. The residue was purified by column chromatography on silica gel with CH$_2$Cl$_2$/AcOEt (5 : 1) to give **31** (257 mg, 85%) as red crystals. M.p. 207−208 °C; IR (AT-IR): v_{max} = 3566 (w), 3366 (w), 3336 (w), 3271 (w), 3216 (w), 2922 (w), 2211 (s), 1678 (s), 1653 (w), 1604 (s), 1536 (s), 1486 (s), 1435 (s), 1413 (w), 1383 (s), 1364 (s), 1317 (w), 1293 (w), 1254 (w), 1174 (m), 1122 (s), 1095 (w), 1065 (w), 985 (w), 950 (w), 852 (w), 817 (s), 794 (w), 769 (w), 747 (m), 737 (m), 714 (w), 689 (w), 676 (m), 656 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} (log ε) = 261 (4.31), 288 sh (3.92), 321 sh (3.41), 359 sh (3.45), 458 (4.47) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 7.54 (d, 2H, J = 9.2 Hz, H$_{3,5}$), 7.33 (s, 1H, furan-H), 6.69 (d, 2H, J = 9.2 Hz, H$_{2,6}$), 5.00 (s, 2H, NH$_2$), 3.11 (s, 6H, NMe$_2$) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 163.22 (C$_{2'}$ of furan), 160.54 [C=C(CN)$_2$], 153.99 (C$_4$), 136.38 (C$_{5'}$ of furan), 132.81 (C$_{3,5}$), 122.97 (C$_{4'}$ of furan), 119.82 (C$_1$), 115.37 (CN), 115.23 (CN), 112.84 (CN), 111.37 (C$_{2,6}$), 73.94 [C(CN)$_2$], 71.37 (C$_{3'}$ of furan), 40.12 (NMe$_2$) ppm; HRMS (MALDI-TOF): calcd for C$_{17}$H$_{13}$N$_5$O + H$^+$ [M + H]$^+$, 304.1193; found: 304.1198.

Compound 32: A solution of **31** (158 mg, 0.521 mmol) in pyrrolidine (5 mL) was stirred at 0 °C for 30 min. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (5 : 1) as an eluent to afford **32** (109 mg, 63%) as yellow crystals. M.p. 278−280 °C (decomp.); IR (AT-IR): v_{max} = 3411 (w), 3326 (w), 3226 (w), 2972 (w), 2879 (w), 2199 (m), 2180 (m), 1635 (w), 1603 (s), 1524 (s), 1477 (w), 1432 (m), 1412 (w), 1362 (s), 1327 (s), 1290 (w), 1243 (m), 1226 (m), 1200 (m), 1173 (w), 1130 (w), 1088 (w), 1066 (w), 1033 (w), 1005 (w),

945 (w), 930 (w), 866 (w), 833 (w), 819 (w), 805 (w), 786 (w), 762 (w), 750 (w), 736 (w), 713 (w), 691 (w), 677 (w), 663 (w) cm^{-1}; UV/Vis (CH$_2$Cl$_2$): λ_{max} (log ε) = 247 (4.36), 279 (4.28), 320 sh (3.82), 377 (4.38), 423 sh (4.06) nm; ^{1}H NMR (500 MHz, CDCl$_3$): δ_H = 7.27 (s, 1H, H$_{6'}$ of pentafulvene), 7.22 (d, 2H, J = 8.7 Hz, H$_{3,5}$), 6.76 (d, 2H, J = 8.7 Hz, H$_{2,6}$), 4.58 (s, 2H, NH$_2$), 4.02 (br. s, 2H, pyrrolidine-H), 3.65 (br. s, 2H, pyrrolidine-H), 3.01 (s, 6H, NMe$_2$), 2.10 (br. s, 2H, pyrrolidine-H), 2.00 (br. s, 2H, pyrrolidine-H) ppm; ^{13}C NMR (125 MHz, CDCl$_3$): δ_C = 156.42 (C$_{4'}$ of pentafulvene), 151.97 (C$_{2'}$ of pentafulvene), 150.63 (C$_4$), 147.86 (C$_{6'}$ of pentafulvene), 131.30 (C$_{3,5}$), 120.66 (C$_1$ or CN), 120.53 (C$_1$ or CN), 116.95 (CN), 112.07 (C$_{2,6}$), 110.54 (C$_{1'}$ of pentafulvene), 90.00 (C$_{3'}$ of pentafulvene), 70.59 (C$_{5'}$ of pentafulvene), 55.87 (pyrrolidine), 52.45 (pyrrolidine), 40.37 (NMe$_2$), 26.55 (pyrrolidine), 24.42 (pyrrolidine) ppm; HRMS (MALDI-TOF): calcd for C$_{20}$H$_{21}$N$_5$$^+$ [M]$^+$ 331.1791; found: 331.1794.

Reaction of 25a with pyrrolidine: A solution of **25a** (238 mg, 0.524 mmol) in pyrrolidine (5 mL) was stirred at room temperature for 30 min. After the reaction, amine was removed under reduced pressure. The crude product was purified by silica gel column chromatography with CH$_2$Cl$_2$/AcOEt (5 : 1) as an eluent to afford **27a** (59 mg, 26%) and **27b** (74 mg, 28%).

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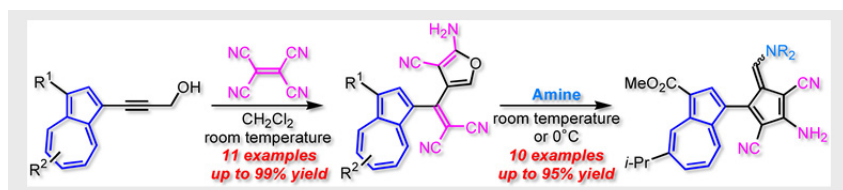
Taku Shoji,* Daichi Nagai, Miwa Tanaka, Takanori Araki, Akira Ohta, Ryuta Sekiguchi, Shunji Ito, Shigeki Mori, and Tetsuo Okujima

Synthesis of 2-Aminofuran derivatives with azulene or *N,N*-dimethylanilino substituent was established by the reaction of 3-(1-azulenyl or *N,N*-dimethylanilino)-2-propyn-1-ols with tetracyanoethylene. 2-Aminofuran derivatives obtained by the reaction were also transformed to 6-aminofulvene derivatives. The structure of 2-aminofuran and 6-aminopentafulvene with *N,N*-dimethylanilino substituent was confirmed by single crystal X-ray structural analysis.