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# Trapping the Lewis Acid Generated Transient Species from Pentafulvene Derived Diazanorbornenes with ortho-Functionalized Aryl lodides and Aliphatic Alcohols 

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#### Abstract

Herein we describe our efforts on the Lewis acid catalyzed stereoselective ring-opening of pentafulvene derived diazabicyclic olefins by using various ortho-functionalized aryl iodides such as 2-iodoanilines, 2iodophenols and 2-iodobenzene thiols to access trans-1,2 disubstituted alkylidenecyclopentenes. Scope of the reaction was also explored with a range of easily available aromatic and aliphatic alcohols. Furthermore, the palladium catalyzed intramolecular Heck cyclization of trans-1,2 disubstituted alkylidenecyclopentenes would provide an easy approach for the synthesis of highly functionalized spiropentacyclic frameworks consisting of a cyclopentene fused to an indoline/benzothiophene and pyrazolidine.


## Introduction

Diazabicyclic olefins have gained much attention in synthetic organic chemistry as a versatile candidate with great synthetic potential. ${ }^{1}$ Desymmetrization of strained diazanorbornenes would provide a step-economic access to a wide variety of biologically relevant complex carbocycles and heterocycles. Synthetic modifications of these strained alkenes have been extensively studied by Micouin et al., ${ }^{2}$ Kaufmann et al., ${ }^{3}$ Pineschi et al., ${ }^{4}$ Lautens et al. ${ }^{5}$ and our research group. ${ }^{6}$ Transition metal catalyzed ring-opening of diazabicyclic olefins with various organometallic reagents, soft nucleophiles and aryl iodides represents an efficient method for the preparation of disubstituted cyclopentenes. ${ }^{2-6}$ Similarly, highly efficient onepot strategies have been developed by the carboannulation or heteroannulation reaction of diazabicyclic alkenes with bifunctionalized reactive species for the construction of functionalized polycyclic molecules. ${ }^{7}$

Synthesis of oxadiazenes was described earlier by the thermal or Lewis acid-catalyzed rearrangement of diazabicyclic olefins, especially $\mathrm{N}, \mathrm{N}$-acyloxy-2,3-diazabicyclo[2.2.1]heptenes. ${ }^{8}$ The reaction pathway was explained on the basis of a [3,3]-sigmatropic rearrangement or an intermediate allylic cation. In 2003, Micouin et al. reported a diastereoselective synthesis of bicyclic cyclopentenes by a protic or Lewis acid catalyzed intramolecular ring-opening of carbobenzyloxyprotected bicyclic [2.2.1] hydrazine through the formation of an
allylic cation. ${ }^{9}$ Later, Lautens et al. reassigned the structure of bicyclic cyclopentenes through X-ray crystallography and suggested a modified mechanism involving a 5-exo-trig cyclization for the ring-forming step. ${ }^{10}$ They have also developed a one-pot protocol towards a variety of $\mathrm{N}^{\prime}$ arylaminooxazolidinones by a Lewis acid catalyzed rearrangement followed by an N -arylation reaction. During the same time Pineschi et al. achieved a regioselective synthesis of trans-1,4-disubstituted hydrazino- and aminocyclopentenes by a sequential copper-catalyzed rearrangement-allylic alkylation of $\mathrm{N}-\mathrm{Cbz}$ protected and $\mathrm{N}-\mathrm{Boc}$ protected Diels-Alder adducts. ${ }^{11}$ A concerted cyclic mechanism, [3,4]-sigmatropic rearrangement was put forward for the intramolecular ringopening of N -Boc protected derivatives. Apart from these reports on the Lewis acid catalyzed intramolecular rearrangement of diazabicyclic olefins, there has been no detailed investigation on the Lewis acid catalyzed intermolecular ring-opening reaction. Very recently, we have described for the first time a Lewis acid catalyzed stereoselective ring-opening of pentafulvene derived diazabicyclic olefins by trapping the transient allylic cation with 2-iodoanilines. ${ }^{12}$ In the same report, we have also demonstrated both step-wise and one-pot Lewis acid/palladium mediated synthesis of novel polycyclic motifs with a cyclopentene fused to an indoline and pyrazolidine.

Cycloaddition chemistry of pentafulvenes is well utilized by various research groups including our own laboratory as an attractive and valuable synthetic tool for the construction of many natural products and pharmaceuticals. ${ }^{13}$ However, the studies on pentafulvene derived diazabicyclic olefins are limited to a few reports on transition metal mediated synthesis of functionalized alkylidenecyclopentenes and heterocycle fused diazabicycles. ${ }^{14}$ Our success in the Lewis acid catalyzed desymmetrization of diazabicyclic olefins with 2-iodoanilines prompted us to elaborate the developed chemistry to other aryl iodides containing hydroxyl or thiol functional groups at the ortho position as well as to various aliphatic alcohols. Herein, we wish to discuss all our efforts on the Lewis acid catalyzed ring-opening of pentafulvene derived diazabicyclic olefins towards trans-1,2 disubstituted alkylidenecyclopentenes, in cooperation with palladium catalyzed intramolecular Heck cyclization to access complex heterocyclic scaffolds.

## Results and Discussions

The bicyclic olefins required for our studies were prepared by the Diels-Alder cycloaddition of various pentafulvenes with azodicarboxylates. ${ }^{1}$ We started our investigations with the reaction of diazabicyclic olefin 1a and 2-iodoaniline 2a in the presence of $\mathrm{Sc}(\mathrm{OTf})_{3}$ in $\mathrm{CH}_{3} \mathrm{CN}$ at room temperature for 12 hours (Scheme 1). The desired 1,2-disubstituted alkylidenecyclopentene 3a was obtained in 45\% yield and the structure of the product was established by various spectroscopic techniques.


Scheme 1. Ring-opening of Fulvene Derived Azabicyclic Olefin with 2-iodoaniline

We have carried out detailed optimization studies to obtain the best condition for the transformation (Table 1). Screening of a range of Lewis acids in different solvents proved that the
reaction in the presence $\mathrm{Sc}(\mathrm{OTf})_{3}$ in toluene at room temperature for 30 minutes is the optimal catalytic condition for the formation of 3a in $93 \%$ yield (Entry 4).

Table 1. Optimization Studies for a Suitable Catalyst System
Entry

Reaction conditions: alkene (3 equiv), 2-iodoaniline (1 equiv), catalyst (2 mol \%), solvent ( 2 mL ), at rt

To test the scope and generality of both the reaction partners, a variety of bicyclic olefins were treated with different 2-iodoanilines under the optimized conditions (Figure 1). All reactions proceeded very smoothly and provided the corresponding alkylidenecyclopentene derivatives in good to excellent yields. The structure and stereochemistry of the compound was unambiguously confirmed by single crystal Xray analysis of $\mathbf{3 a} .{ }^{15}$

After accomplishing the promising results with 2iodoanilines, we were interested in trapping the transient species from pentafulvene derived diazanorbornenes with other nucleophiles. With this idea in mind, the diazabicyclic olefin 1a was treated with 2-iodophenol 4a under the same optimal reaction conditions employed in the case of 2-iodoanilines. As expected, 1,2-disubstituted alkylidenecyclopentene 5a was formed in $43 \%$ yield (Scheme 2).



Figure 1. Substrate Scope of Various Diazabicyclic Olefins and 2-Iodoanilines

Detailed screening studies were performed by choosing 2a and $\mathbf{4 a}$ as the model substrates to accomplish the optimal reaction conditions and our efforts are summarized in table 2. Among the various Lewis acids surveyed, AgOTf gave better yield compared to other Lewis acids such as $\mathrm{Sc}(\mathrm{OTf})_{3}$, $\mathrm{Yb}(\mathrm{OTf})_{3}, \mathrm{Cu}(\mathrm{OTf})_{2}, \mathrm{Sn}(\mathrm{OTf})_{2}, \mathrm{BF}_{3} \mathrm{Et}_{2} \mathrm{O}$ and $\mathrm{B}\left(\mathrm{C}_{6} \mathrm{~F}_{5}\right)_{3}$. An extensive screening of the solvents revealed that $\mathrm{CH}_{3} \mathrm{CN}$ was more proficient than toluene, DMF, acetone and DCM. The role of various bases in the Lewis acid catalyzed ring-opening was next examined and perceived that $\mathrm{Na}_{2} \mathrm{CO}_{3}$ was superior to other bases such as $\mathrm{K}_{2} \mathrm{CO}_{3}, \mathrm{Cs}_{2} \mathrm{CO}_{3}$ and $\mathrm{Et}_{3} \mathrm{~N}$. Eventually, diazabicyclic olefin 1a and 2-iodophenol 4a in the presence of AgOTf and $\mathrm{Na}_{2} \mathrm{CO}_{3}$ in acetonitrile at room temperature for 4 hours was found to be the best reaction condition (Entry 16).


Scheme 2. Lewis Acid Catalyzed Desymmetrization of Fulvene Derived Diazabicyclic Olefin with 2-Iodophenol

With the optimal catalytic conditions in hand, we explored the ring-opening of various pentafulvene derived diazabicyclic olefins with different 2 -iodophenols (Figure 2). It is to be noted that 2-iodophenols bearing different functional groups such as $\mathrm{NO}_{2}, \mathrm{CO}_{2} \mathrm{Me}$ and phenyl were successfully employed in the developed method. The corresponding functionalized alkylidenecyclopentenes were formed in moderate to good yields through the ring-opening of diazabicyclic olefins.

Table 2. Optimization Data for the Ring-Opening of Diazabicyclic Olefin with 2-Iodophenol

|  |  | 4 |  |  |
| :---: | :---: | :---: | :---: | :---: |
| Entry | Lewis acid | Solvent | Base | Yield (\%) |
| 1 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | toluene | - | 43\% |
| 2 | $\mathrm{Yb}(\mathrm{OTf})_{3}$ | toluene | - | 24\% |
| 3 | $\mathrm{Cu}(\mathrm{OTf})_{2}$ | toluene | - | 29\% |
| 4 | $\mathrm{Sn}(\mathrm{OTf})_{2}$ | toluene | - | 16\% |
| 5 | $\mathrm{BF}_{3} . \mathrm{Et}_{2} \mathrm{O}$ | toluene | - | 25\% |
| 6 | $\mathrm{B}\left(\mathrm{C}_{6} \mathrm{~F}_{5}\right)_{3}$ | toluene | - | 18\% |
| 7 | AgOTf | toluene | - | 52\% |
| 8 | Agotf | DMF | - | 20\% |
| 9 | AgOtf | Acetone | - | 20\% |
| 10 | AgOtf | DCM | - | 17\% |
| 11 | AgOTf | Toluene | - | 37\% |
| 12 | AgOTf | $\mathrm{CH}_{3} \mathrm{CN}$ | - | 54\% |
| 13 | AgOTf | $\mathrm{CH}_{3} \mathrm{CN}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | 20\% |
| 14 | AgOtf | $\mathrm{CH}_{3} \mathrm{CN}$ | $\mathrm{K}_{2} \mathrm{CO}_{3}$ | 52\% |
| 15 | Agotf | $\mathrm{CH}_{3} \mathrm{CN}$ | $\mathrm{Et}_{3} \mathrm{~N}$ | 30\% |
| 16 | AgOTf | $\mathrm{CH}_{3} \mathrm{CN}$ | $\mathrm{Na}_{2} \mathrm{CO}_{3}$ | 63\% |

Reaction conditions: alkene (3 equiv), 2-iodophenol (1 equiv), catalyst (2 $\mathrm{mol} \%$ ), base ( 1.5 equiv), solvent ( 2 mL ), at rt

In the next stage we have elaborated the scope of orthosubstituted aryl iodides to another class of nucleophiles, 2-
iodobenzene thiols. We initiated our studies with the reaction of diazabicyclic olefin 1a and 2-iodobenzene thiol $\mathbf{6 a}$ in the presence of $\mathrm{Sc}(\mathrm{OTf})_{3}$ in toluene at room temperature for 2 hours. The reaction afforded the desired 1,2-disubstiituted alkylidenecyclopentene $\mathbf{7 a}$ in $66 \%$ yield (Scheme 3 ).


Figure 2. Substrate Scope of 2-lodophenols

To obtain the best catalyst system for the transformation, a detailed investigation on various reaction parameters was performed (Table 3). Initially a thorough screening of Lewis acids was carried out and $\mathrm{Zn}(\mathrm{OTf})_{2}$ was found to be the most effective catalyst. Examination of the role of solvents revealed toluene as the favourable reaction medium than THF, DCM and $\mathrm{CH}_{3} \mathrm{CN}$. Finally, the optimized reaction conditions were obtained as: 1a and $\mathbf{6 a}$ in the presence of $\mathrm{Zn}(\mathrm{OTf})_{2}$ as Lewis acid in toluene at room temperature for 2 hours.


Scheme 3. Lewis Acid Catalyzed Desymmetrization of Fulvene Derived Diazabicyclic Olefin with 2-Iodobenzene Thiol

The reaction was found to be compatible with a range of diazabicyclic olefins and 2-iodobenzene thiols under the optimal conditions. Diazabicyclic olefins smoothly reacted with a range of 2-iodobenzene thiols and afforded the functionalized alkylidenecyclopentenes in moderate to good yields.

Table 3. Optimization Studies for the Best Reaction Condition

| Entry | Lewis acid | Solvent | Yield (\%) |
| :---: | :---: | :---: | :---: |
| 1 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | toluene | 66 |
| 2 | $\mathrm{Zn}(\mathrm{OTf})_{2}$ | toluene | 70 |
| 3 | $\mathrm{Yb}(\mathrm{OTf})_{3}$ | toluene | 53 |
| 4 | $\mathrm{Cu}(\mathrm{OTf})_{2}$ | toluene | 39 |
| 5 | AgOTf | toluene | 37 |
| 6 | $\mathrm{BF}_{3} . \mathrm{Et}_{2} \mathrm{O}$ | toluene | 36 |
| 7 | $\mathrm{Fe}(\mathrm{OTf})_{3}$ | toluene | 45 |
| 8 | $\mathrm{Zn}(\mathrm{OTf})_{2}$ | THF | 76 |
| 9 | $\mathrm{Zn}(\mathrm{OTf})_{2}$ | DCM | 67 |
| 10 | $\mathrm{Zn}(\mathrm{OTf})_{2}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 69 |

Reaction conditions: alkene (3 equiv), 2-iodobenzene thiol (1 equiv), catalyst ( $2 \mathrm{~mol} \%$ ), solvent ( 2 mL ), at $\mathrm{rt}, 2 \mathrm{~h}$.

Finally, we have expanded our studies to the ring-opening of diazabicyclic olefins with simple aliphatic and aromatic alcohols under Lewis acid catalysis. In a pilot experiment, bicyclic alkene 1a was treated with benzyl alcohol 8a in the presence of $\mathrm{Sc}(\mathrm{OTf})_{3}$ in toluene at room temperature for 1 hour and the reaction afforded the ring-opened product $9 \mathbf{h}$ in $68 \%$ yield.


Scheme 4. Lewis Acid Catalyzed Desymmetrization of Fulvene Derived Diazabicyclic Olefin with Benzyl Alcohol

After an extensive screening of Lewis acids and solvents, $\mathrm{Cu}(\mathrm{OTf})_{2}$ in toluene was found to be the most suitable catalyst system for the ring-opening of bicyclic olefins with alcohols.


Figure 3. Substrate Scope of 2-Iodobenzene Thiols

Table 4. Screening of Various Lewis Acids and Different Solvents towards Ring-Opening of Diazabicyclic Olefin

|  | $\mathrm{CO}_{2} \mathrm{Et}$  <br> 8a |  |  |
| :---: | :---: | :---: | :---: |
| Entry | Lewis acid | Solvent | Yield (\%) |
| 1 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | toluene | 68 |
| 2 | $\mathrm{Yb}(\mathrm{OTf})_{3}$ | toluene | 33 |
| 3 | $\mathrm{Zn}(\mathrm{OTf})_{2}$ | toluene | 43 |
| 4 | $\mathrm{La}(\mathrm{OTf})_{3}$ | toluene | 66 |
| 5 | $\mathrm{Cu}(\mathrm{OTf})_{2}$ | toluene | 72 |
| 6 | $\mathrm{Fe}(\mathrm{OTf})_{3}$ | toluene | 35 |
| 7 | AgOTf | toluene | 45 |
| 8 | $\mathrm{Cu}(\mathrm{OTf})_{2}$ | THF | 29 |
| 9 | $\mathrm{Cu}(\mathrm{OTf})_{2}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | NR |
| 10 | $\mathrm{Cu}(\mathrm{OTf})_{2}$ | DCM | NR |

Reaction conditions: Azabicyclic olefin (3.0 equiv.), alcohol (1.0 equiv.), Lewis acid ( $5 \mathrm{~mol} \%$ ), solvent ( 2.5 mL ), rt, 1 hour.

A variety of alcohols were applied in the developed method for the ring-opening of diazabicyclic olefins. The reaction was also found to proceed well with 2-iodobenzyl alcohol and produced the desired alkylidenecyclopentene $\mathbf{9 i}$ in $55 \%$ yield. Interestingly, the reaction is tolerant of different aliphatic alcohols such as methanol, ethanol, propargyl alcohol etc. under the optimal catalytic conditions. Ring-opening of bicyclic olefins underwent very efficiently with various substituted aliphatic alcohols and afforded the corresponding alkylidenecyclopentene derivatives in moderate to good yields (Figure 4).


Figure 4. Substrate Scope of aliphatic and aromatic alcohols

Based on the results we propose a plausible mechanism for the Lewis acid catalyzed ring-opening of diazabicyclic olefins (Scheme 5). In the first step, Lewis acid is co-ordinated to the carbonyl group of diazabicyclic olefin. The susequent cleavage of C-N bond leads to a transient allylic cation species B. Attack of the incoming nucleophile from the opposite face furnishes trans-1,2-disubstituted alkylidenecyclopentenes.


Scheme 5. Plausible Mechanism

To further explore the synthetic utility of the synthesized 1,2-disubstituted alkylidenecyclopentenes derived by the ringopening with 2-iodoanilines, we have carried out an intramolecular Heck cyclization. Our attempts commenced with the treatment of an alkylidenecyclopentene with $\mathrm{Pd}(\mathrm{OAc})_{2}$, $\mathrm{PPh}_{3}$ and $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ in $\mathrm{CH}_{3} \mathrm{CN}$ at $80{ }^{\circ} \mathrm{C}$ (Scheme 6). To our delight, instead of the usual Heck cyclized product, a novel spiropentacyclic motif with a cyclopentene fused to an indoline and pyrazolidine $\mathbf{1 0 h}$ was formed in $72 \%$ yield. The reaction proceeds through the intramolecular Heck reaction followed by the generation of a $\pi$-allyl palladium complex and subsequent intramolecular nucleophilic attack by the hydrazine -NH .


Scheme 6. Synthesis of Indoline Dreivative by Intramolecular Heck Cyclization

Owing to the prominence of indoline and pyrazolidine motifs, the generality of the intramolecular Heck cyclization was proved by the reaction of various alkylidenecyclopentenes and the results are depicted in table 5. 1,2-disubstituted alkylidene cyclopentenes derived from various diazabicyclic olefins and 2-iodoanilines smoothly underwent intramolecular Heck cyclization and produced the corresponding spiropentacyclic motifs in good yields.

A plausible mechanism is shown in Scheme 7 for the formation of indoline-pyrazolidine fused cyclopentene. Initially, the oxidative addition of $\operatorname{Pd}(0)$ to the aryl iodide leads to the formation of $\mathbf{A}$. Intermediate $\mathbf{A}$ thus formed is
coordinated to the double bond of cyclopentene followed by the generation of a $\pi$-allylpalladium complex, the key intermediate C. The intramolecular nucleophilic attack of the hydrazine moiety to the $\pi$-allylpalladium complex provides the polycycle.

## Table 5. Substrate Scope for Intramolecular Heck Cyclization

Entry


Scheme 7. Proposed Catalytic Cycle for the Intramolecular Heck Cyclization


Scheme 8. Synthesis of Derivatized Dihydrobenzothiophene by Intramolecular Heck Cyclization

In the next stage, we envisaged the synthesis of a highly functionalized spiropentacyclic framework consisting of a cyclopentene fused to a benzothiophene and pyrazolidine. With this objective, we have applied the intramolecular Heck cyclization strategy to the alkylidinecyclopentene derivative formed by the ring-opening of diazanorbornene 2a with 2iodobenzene thiol. The reaction resulted in the formation of a polycyclic scaffold with a cyclopentene fused to a benzothiophene and pyrazolidine 11a in $34 \%$ yield. Screening studies showed that NaOAc provided the product in $41 \%$ yield (Scheme 8). Unfortunately, our efforts on the intramolecular cyclization of alkylidenecyclopentenes formed through the ring opening of diazabicyclic olefins with 2-iodophenols are not successful so far.

Table 6. Optimization studies for the one pot synthesis of indolinepyrazolidine fused cyclopentenes

| Entry | Lewis acid | Pd Catalyst | Ligand | Base | Solvent T | Temperature ( $\left.{ }^{\circ} \mathrm{C}\right)$ |  | $\begin{gathered} d \% \\ 4 \end{gathered}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}(\mathrm{OAc})_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | 20 | 28 |
| 2 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}(\mathrm{OAc})_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{K}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | 10 | 21 |
| 3 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}(\mathrm{OAc})_{2}$ | PPh ${ }_{3}$ | KOAc | $\mathrm{CH}_{3} \mathrm{CN}$ | 60 | trace amount |  |
| 4 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}(\mathrm{OAc})_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Et}_{3} \mathrm{~N}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 60 | 15 | trace |
| 5 | $\mathbf{S c}(\mathrm{OTf})_{3}$ | $\mathrm{PdCl}_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 60 | 25 | trace |
| 6 | $\mathbf{S c}(\mathrm{OTf})_{3}$ | $\left[\mathrm{Pd}\right.$ (allyl) $\mathrm{Cl}^{\text {] }}{ }_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 60 | - | 28 |
| 7 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}(\mathrm{OAc})_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | trace 42 |  |
| 8 | $\mathbf{S c}(\mathrm{OTf})_{3}$ | $\mathrm{PdCl}_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | trace amount |  |
| 9 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}\left(\mathrm{PPh}_{3}\right)_{4}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | trace amount |  |
| 10 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $[\mathrm{Pd}(\mathrm{allyl}) \mathrm{Cl}]_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | - | 51 |
| 11 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $\mathrm{Pd}(\mathrm{dba})_{3} \mathrm{CHCl}_{3}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | - | 12 |
| 12 | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $[\mathrm{Pd}(\text { ally } \mathrm{l}) \mathrm{Cl}]_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}$ | 80 | - | 55 |
| $13^{\text {a }}$ | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $[\mathrm{Pd}(\mathrm{allyl}) \mathrm{Cl}]_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}+$ Toluene | + 80 | - | 58 |
| $14^{4}$ | $\mathbf{S c}(\mathrm{OTf})_{3}$ | $\left[\mathrm{Pd}\right.$ (allyl) $\mathrm{Cl}_{3}{ }_{2}$ | $\mathrm{PPh}_{3}$ | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}+$ <br> Toluene | + 70 | - | 14 |
| $15$ | $\mathrm{Sc}(\mathrm{OTf})_{3}$ | $[\mathrm{Pd}(\mathrm{allyl}) \mathrm{Cl}]_{2}$ | dppe | $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ | $\mathrm{CH}_{3} \mathrm{CN}+$ <br> Toluene | 70 | - | 18 |

Reaction Conditons: alkene ( 3 equiv), 2 -iodoaniline ( 1 equiv), catalyst ( 5 mol $\%$ ), base ( 1.5 equiv), ligand ( $10 \mathrm{~mol} \%$ ), Lewis acid ( $2 \mathrm{~mol} \%$ ), solvent ( 2.5 $\mathrm{mL})$ at $80{ }^{\circ} \mathrm{C},{ }^{\mathrm{a}} \mathrm{CH}_{3} \mathrm{CN}$ :Toluene $(2: 0.5)$

Ultimately, we have performed the tandem reactions to investigate the one-pot synthesis of spiropentacyclic motifs with a cyclopentene fused to an indoline and pyrazolidine. In an initial endeavour, the treatment of pentafulvene derived diazabicyclic olefin 1a with 2-iodoaniline 2a in the presence of $\mathrm{Sc}(\mathrm{OTf})_{3}, \mathrm{Pd}(\mathrm{OAc})_{2}, \mathrm{PPh}_{3}$ and $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ in $\mathrm{CH}_{3} \mathrm{CN}$ afforded the
functionalized polycycle in $28 \%$ yield along with alkylidencyclopentene in $20 \%$ yield. The best catalytic system for the one-pot transformation was achieved after an extensive screening of various reaction parameters. The reaction of $\mathbf{1 a}$ and 2a in the presence of $[\mathrm{Pd}(\text { allyl }) \mathrm{Cl}]_{2}(5 \mathrm{~mol} \%), \mathrm{Sc}(\mathrm{OTf})_{3}(2$ $\mathrm{mol} \%), \mathrm{PPh}_{3}(10 \mathrm{~mol} \%)$ and $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ (1.5 equiv) in 2:0.5 mixture of acetonitrile-toluene led to the exclusive formation of spiropentacyclic molecule in $58 \%$ yield (Scheme 9).


Scheme 9. One Pot Synthesis of Indoline Derivative

Under the optimized reaction conditions various pentafulvene derived bicyclic olefins and 2-iodo anilines were successfully employed for the synthesis of corresponding spiropentacyclic motifs in good yields (Table 7).

Table 7. Substrate Scope for One Pot Strategy


## Conclusions

In summary, we have demonstrated a Lewis acid catalyzed stereoselective ring-opening of pentafulvene derived diazabicyclic olefins by using various ortho-functionalized aryl iodides and aliphatic alcohols to access trans-1,2 disubstituted alkylidenecyclopentenes. The palladium catalyzed intramolecular Heck cyclization of trans-1,2 disubstituted alkylidenecyclopentenes provides an efficient method for the synthesis of highly functionalized spiropentacyclic frameworks consisting of cyclopentene fused to an indoline/benzothiophene and pyrazolidine. The developed strategy is an integration of the transient species generated by Lewis acid and $\pi$-allyl palladium complex. Both one-pot and step-wise synthetic strategies toward functionalized heterocyclic scaffolds are discussed in detail. Further studies to explore the scope of other nucleophiles in trapping the transient species from diazabicyclic olefins and synthesis of other polycyclic scaffolds are in progress.

## Experimental

## General

All chemicals were of the best grade commercially available and are used without further purification. All solvents were purified according to standard procedure; dry solvents were obtained according to the literature methods and stored over molecular sieves. Analytical thin layer chromatography was performed on glass plates coated with silica gel containing calcium sulfate binder. Gravity column chromatography was performed using $60-120$ or 100-200 mesh silica gel and mixtures of hexane-ethyl acetate were used for elution.

Melting points were determined on a Buchi melting point apparatus and are uncorrected. Proton nuclear magnetic resonance spectra ( ${ }^{1} \mathrm{H}$ NMR) were recorded on a Bruker Avance DPX 300 and Bruker AMX 500 spectrophotometer $\left(\mathrm{CDCl}_{3}\right.$ as solvent). Chemical shifts for ${ }^{1} \mathrm{H}$ NMR spectra are reported as $\delta$ in units of parts per million ( ppm ) downfield from SiMe4 ( $\delta 0.0$ ) and relative to the signal of chloroform-d ( $\delta 7.25$, singlet). Multiplicities were given as: s (singlet); d (doublet); t (triplet); $q$ (quadret); dd (double doublet); $m$ (multiplet). Coupling constants are reported as $J$ value in Hz . Carbon nuclear magnetic resonance spectra ( ${ }^{13} \mathrm{C}$ NMR) are reported as $\delta$ in units of parts per million (ppm) downfield from $\mathrm{SiMe}_{4}$ ( $\delta$ $0.0)$ and relative to the signal of chloroform-d ( $\delta 77.03$, triplet). Mass spectra were recorded under EI/HRMS at 60,000 resolution using Thermo Scientific Exactive mass spectrometer. IR spectra were recorded on Bruker FT-IR spectrometer.

## Characterization data of the compounds

General procedure for the Lewis acid catalyzed reaction of pentafulvene derived bicyclic hydrazines with 2-iodoaniline
A mixture of pentafulvene derived diazabicyclic olefin (3.0 eqiuv), $o$-iodoaniline ( 1.0 equiv) and $\mathrm{Sc}(\mathrm{OTf})_{3}(2 \mathrm{~mol} \%)$ were
weighed in a schlenk tube and degassed for 10 minutes. Dry toluene ( 2 ml ) was added and the reaction mixture was purged with argon and allowed to stir at room temperature for 30 minutes. The solvent was evaporated in vacuo and the residue on silica gel (100-200 mesh) column chromatography yielded trans-3,4-disubstituted alkylidene cyclopentene.

Diethyl 1-(-2-cyclohexylidene-5-(2-iodophenylamino) cyclopent-3-enyl)hydrazine-1,2-dicarboxylate (3a)
Yield: $93 \%$ as pale yellow coloured solid (m.p $=132-134^{\circ} \mathrm{C}$ ); $\mathrm{R}_{\mathrm{f}}$ : 0.46 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3387,3284$, 3063, 2980, 2928, 2853, 1709, 1586, 1499, 1449, 1410, 1381, 1313, 1281, 1228, 1171, 1123, 1061, 1007, 928, 741 $\mathrm{cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.64(\mathrm{~s}, 1 \mathrm{H}), 7.22(\mathrm{~s}, 1 \mathrm{H})$, $7.00-6.84(\mathrm{~m}, 1 \mathrm{H}), 6.65(\mathrm{~d}, J=5 \mathrm{~Hz}, 1 \mathrm{H}), 6.44(\mathrm{t}, J=7 \mathrm{~Hz}$, $1 \mathrm{H}), 6.21-6.17(\mathrm{~m}, 1 \mathrm{H}), 5.95(\mathrm{~s}, 1 \mathrm{H}), 5.10-4.92(\mathrm{~m}, 2 \mathrm{H}), 4.23-$ $4.08(\mathrm{~m}, 5 \mathrm{H}), 2.33(\mathrm{t}, J=5.5 \mathrm{~Hz}, 2 \mathrm{H}), 2.07(\mathrm{~s}, 2 \mathrm{H}), 1.66-1.44$ $(\mathrm{m}, 6 \mathrm{H}), 1.29-1.12(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 156.4,155.2,146.1,138.8,134.2,132.3,132.1,129.5$, $119.5,112.9,112.3,85.5,64.7,63.4,62.8,62.1,31.8,31.4$, 28.2, 28.0, 26.4, 14.5. MS (ESI): Calcd for $\mathrm{C}_{23} \mathrm{H}_{30} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 562.11787; Found: $562.11481\left(\mathrm{C}_{23} \mathrm{H}_{30} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

Diethyl 1-(-2-(2-iodo-4-nitrophenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3b)

Yield: $73 \%$ as pale yellow viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.43$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3369,3258,2921$, $1731,1560,1418,1375,1280,1213,1112,1054,1002,751 \mathrm{~cm}^{-}$ ${ }^{1}$. ${ }^{1} \mathbf{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 8.56(\mathrm{~d}, J=10 \mathrm{~Hz}$, $1 \mathrm{H}), 8.17(\mathrm{~d}, J=9 \mathrm{~Hz}, 1 \mathrm{H}), 7.05(\mathrm{~m}, 1 \mathrm{H}), 6.67(\mathrm{~d}, J=5 \mathrm{~Hz}$, $1 \mathrm{H}), 6.27-6.19(\mathrm{~m}, 1 \mathrm{H}), 5.92(\mathrm{~s}, 1 \mathrm{H}), 5.01-4.79(\mathrm{~m}, 2 \mathrm{H}), 4.27-$ $4.09(\mathrm{~m}, 5 \mathrm{H}), 1.89(\mathrm{~s}, 3 \mathrm{H}), 1.69(\mathrm{~s}, 3 \mathrm{H}), 1.29(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.6,154.7,151.0,138.6$, $135.1,134.8,130.4,126.2,125.9,112.2,110.4,82.4,65.6$, 64.1, 63.3, 62.2, 21.5, 20.9, 14.6, 14.1. MS (ESI): Calcd for $\mathrm{C}_{20} \mathrm{H}_{25} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}$ : 567.07165 ; Found: 567.07123 $\left(\mathrm{C}_{20} \mathrm{H}_{25} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}\right)$.

Diethyl 1-(-2-(2-iodo-4-(trifluoromethyl) phenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl)hydrazine-1,2 dicarboxylate (3c)
Yield: $67 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.40 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3379,3280,2988,2920,2868$, $1714,1580,1478,1450,1368,1301,1224,1129,931,749 \mathrm{~cm}^{-1}$. ${ }^{1} \mathbf{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.85(\mathrm{~d}, J=13 \mathrm{~Hz}, 1 \mathrm{H})$, $7.48(\mathrm{~s}, 1 \mathrm{H}), 7.12-7.02(\mathrm{~m}, 1 \mathrm{H}), 6.63(\mathrm{~s}, 1 \mathrm{H}), 6.19-6.14(\mathrm{~m}$, $1 \mathrm{H}), 5.93(\mathrm{~s}, 1 \mathrm{H}), 5.05(\mathrm{~d}, J=15.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.87(\mathrm{~s}, 1 \mathrm{H}), 4.40$ (d, $J=11.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.23-4.11(\mathrm{~m}, 4 \mathrm{H}), 1.99(\mathrm{~s}, 3 \mathrm{H}), 1.68(\mathrm{~s}$, 3H), 1.32-1.25 (m, 6H). ${ }^{13}$ C NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $156.4,155.1,148.5,135.8,135.2,134.8,131.0,127.0,126.7$, 120.5, 111.6, 83.7, 63.9, 63.3, 62.9, 62.2, 21.4, 20.5, 14.5. MS (ESI): Calcd for $\mathrm{C}_{21} \mathrm{H}_{25} \mathrm{~F}_{3} \quad \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 590.07395; Found: $590.07257\left(\mathrm{C}_{21} \mathrm{H}_{25} \mathrm{~F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

Diisopropyl 1-(-2-(2-iodophenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3d)

Yield: $84 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.45$ (hexane/ethyl acetate $=3: 1$ ). $\mathbf{I R}$ (Neat) $v_{\max }: 3375,3280,2979,2934,2850$, 1730, 1580, 1490, 1446, 1403, 1314, 1280, 1220, 1120, 1060, 1000, $931,741 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 7.61$ $(\mathrm{d}, J=8 \mathrm{~Hz}, 1 \mathrm{H}), 7.23-7.19(\mathrm{~m}, 1 \mathrm{H}), 7.02(\mathrm{brs}, 1 \mathrm{H}), 6.59(\mathrm{~d}, J$ $=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.65-6.41(\mathrm{~m}, 1 \mathrm{H}), 6.16-6.05(\mathrm{~m}, 1 \mathrm{H}), 5.94(\mathrm{~s}$, $1 \mathrm{H}), 5.05-4.89(\mathrm{~m}, 4 \mathrm{H}), 4.05(\mathrm{~s}, 1 \mathrm{H}), 1.87(\mathrm{~s}, 3 \mathrm{H}), 1.68(\mathrm{~s}, 3 \mathrm{H})$, 1.28-1.09 (m, 12H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ $156.1,154.8,146.1,138.9,135.6,131.8,129.7$, 127.2, 125.3, $118.8,112.9,85.4,70.8,70.0,65.1,63.6,26.9,25.3,22.1,21.9$, 21.5, 20.7. MS (ESI): Calcd for $\mathrm{C}_{22} \mathrm{H}_{30} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}: ~ 550.11787$; Found: $550.11633\left(\mathrm{C}_{22} \mathrm{H}_{30} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Diisopropyl 1-(-2-(2-iodo-4-(trifluoromethyl) phenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2dicarboxylate (3e)

Yield: $66 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.43 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3295,2940,2850,1713,1580$, 1481, 1411, 1281, 1220, 1123, 1061, 1001, $920,741 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.84(\mathrm{~d}, J=11 \mathrm{~Hz}, 1 \mathrm{H})$, $7.48(\mathrm{~d}, J=8 \mathrm{~Hz}, 1 \mathrm{H}), 7.16-7.06(\mathrm{~m}, 1 \mathrm{H}), 6.63(\mathrm{~s}, 1 \mathrm{H}), 6.14-$ $6.06(\mathrm{~m}, 1 \mathrm{H}), 5.92(\mathrm{~s}, 1 \mathrm{H}), 5.05-4.87(\mathrm{~m}, 4 \mathrm{H}), 4.43-4.38(\mathrm{~m}$, $1 \mathrm{H}), 1.88(\mathrm{~s}, 3 \mathrm{H}), 1.68(\mathrm{~s}, 3 \mathrm{H}), 1.32-1.03(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.8,154.7,148.4,136.1,135.9$, $134.8,130.7,128.9,126.9,125.2,120.2,113.4,111.6,83.7$, 70.2, 65.4, 63.7, 63.1, 26.9, 25.2, 22.6, 21.9, 21.4, 20.7. MS (ESI): Calcd for $\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{~F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 618.10525; Found: $618.10495\left(\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{~F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Dibenzyl 1-(-2-(2-iodophenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3f)

Yield: $72 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.48$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3386,3287,3063,3032,2926$, 2852, 1716, 1586, 1489, 1450, 1402, 1313, 1283, 1128, 1077, 1050, 1004, 894, $743,698 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 7.60(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.52-7.04(\mathrm{~m}, 12 \mathrm{H}), 6.79(\mathrm{~s}$, $1 \mathrm{H}), 6.55-6.32(\mathrm{~m}, 3 \mathrm{H}), 5.92-5.86(\mathrm{~m}, 1 \mathrm{H}), 5.29-4.85(\mathrm{~m}, 5 \mathrm{H})$, 4.05 (brs, 1H), $1.81(\mathrm{~s}, 3 \mathrm{H}), 1.58(\mathrm{~m}, 3 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR (125 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 156.6,155.2,145.9,145.3,138.9,137.4$, $135.7,135.4,134.2,131.7,129.7,128.6,128.4,128.2,128.1$, $119.0,112.7,85.5,68.2,67.7,65.8,63.5,21.8,21.4$. MS (ESI): Calcd for $\mathrm{C}_{30} \mathrm{H}_{30} \mathrm{IN}_{3} \mathrm{O}_{4}, \mathrm{M}^{+}$: 623.12810; Found: $(\mathrm{M}+1)$ 624.13416.

## Dibenzyl 1-(-2-(2-iodo-4-(trifluoromethyl) phenylamino)-5-(propan-2-ylidene)cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3g)

Yield: $68 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.51 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3084,2385,3060,3038,2932$, 2850, 1718, 1586, 1494, 1451, 1402, 1284, 1403, 1311, 1280, 1210, 1124, 1051, 1010, 916, 741, $690 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR (500 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.81(\mathrm{~s}, 1 \mathrm{H}), 7.32-7.10(\mathrm{~m}, 12 \mathrm{H}), 6.58$ $(\mathrm{d}, J=6 \mathrm{~Hz}, 1 \mathrm{H}), 6.36(\mathrm{~s}, 1 \mathrm{H}), 5.87(\mathrm{~d}, J=12 \mathrm{~Hz}, 1 \mathrm{H}), 5.18-$ $4.92(\mathrm{~m}, 6 \mathrm{H}), 4.39($ brs, 1 H$), 1.83(\mathrm{~s}, 3 \mathrm{H}), 1.59(\mathrm{~s}, 3 \mathrm{H}) .{ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.9,155.2,148.3,135.8$, $135.1,128.6,128.5,128.1,127.1,120.2,111.5,83.8,68.4$,
67.8, 64.1, 63.2, 21.5, 20.6. MS (ESI): Calcd for $\mathrm{C}_{31} \mathrm{H}_{29}$ $\mathrm{F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}: \quad 714.10325$ : Found: $714.10339 \quad\left(\mathrm{C}_{31} \mathrm{H}_{29}\right.$ $\mathrm{F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ ).

Diethyl 1-(-2-(2-iodophenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3h)
Yield: $90 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.31 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3383,3280,3054,2976,2928$, 2853, 1709, 1586, 1499, 1149, 1410, 1330, 1220, 1120, 1052, 1011, $920,745 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): 7.61 $(\mathrm{s}, 1 \mathrm{H}), 7.20(\mathrm{~s}, 1 \mathrm{H}), 6.99-6.80(\mathrm{brs}, 1 \mathrm{H}), 6.59(\mathrm{~d}, J=3.5 \mathrm{~Hz}$, $1 \mathrm{H}), 6.42(\mathrm{t}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.30-6.16(\mathrm{~m}, 1 \mathrm{H}), 5.94(\mathrm{~s}, 1 \mathrm{H})$, $5.07-4.80(\mathrm{~m}, 2 \mathrm{H}), 4.22-4.05(\mathrm{~m}, 5 \mathrm{H}), 1.87(\mathrm{~s}, 3 \mathrm{H}), 1.68(\mathrm{~s}$, $3 \mathrm{H}), 1.28-1.11(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $156.8,155.2,146.0,138.8,135.5,134.2,131.9,129.4,118.9$, $112.8,85.5,65.3,63.8,62.8,62.0,21.4,20.6,14.5$. MS (ESI): Calcd for $\mathrm{C}_{20} \mathrm{H}_{26} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 522.08657; Found: 522.08608 $\left(\mathrm{C}_{20} \mathrm{H}_{26} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

Diethyl 1-(-2-cyclohexylidene-5-(2-iodo-4-nitrophenylamino) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3i)

Yield: $78 \%$ as yellow viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.53 (hexane/ethyl acetate $=6: 4$ ). IR (Neat) $v_{\max }: 3464,3365,3071,2920,2852$, $1705,1623,1582,1469,1410,1380,1318,1173,1115,1058$, $743 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 8.59-8.57($ $\mathrm{m}, 1 \mathrm{H}), 8.19-8.15(\mathrm{~m}, 1 \mathrm{H}), 7.07-7.01(\mathrm{~m}, 1 \mathrm{H}), 6.74-6.69(\mathrm{~m}$, $1 \mathrm{H}), 6.24-6.19(\mathrm{~m}, 1 \mathrm{H}), 5.93(\mathrm{~s}, 1 \mathrm{H}), 5.10-4.83(\mathrm{~m}, 3 \mathrm{H}), 4.26-$ $4.12(\mathrm{~m}, 4 \mathrm{H}), 2.39-2.34(\mathrm{~m}, 2 \mathrm{H}), 2.07-2.05(\mathrm{~m}, 2 \mathrm{H}), 1.59$ (brs, $6 \mathrm{H}), 1.30-1.16(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ $156.8,154.8,150.9,138.5,135.2,131.7,130.5,126.3,125.7$, $112.3,110.4,82.5,64.9,63.5,62.9,62.4,31.9,30.9,29.7,28.3$, 26.3, 14.6, 14.1. MS (ESI): Calcd for $\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}$ : 607.10295; Found: $607.10139\left(\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}\right)$.

## Diisopropyl 1-(-2-cyclohexylidene-5-(2-iodophenylamino) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3j)

Yield: $84 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.48 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3387,3285,2979,2927,2853$, $1721,1706,1587,1497,1451,1384,1316,1282,1107,1037$, $1005,743 \mathrm{~cm}^{-1} ;{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.61(\mathrm{~d}, J$ $=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.23-7.16(\mathrm{~m}, 1 \mathrm{H}), 7.04-6.84(\mathrm{~m}, 1 \mathrm{H}), 6.64(\mathrm{~d}, J$ $=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.42(\mathrm{t}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.11-6.03(\mathrm{~m}, 1 \mathrm{H}), 5.95$ $(\mathrm{s}, 1 \mathrm{H}), 5.07-4.82(\mathrm{~m}, 4 \mathrm{H}), 4.07$ (brs, 1 H$), 2.34(\mathrm{brs}, 2 \mathrm{H}), 2.09$ ( $\mathrm{s}, 2 \mathrm{H}$ ), 1.57 (brs, 6 H ), 1.28-1.17 (m, 12H). ${ }^{13} \mathrm{C}$ NMR ( 125 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 155.9,154.5,146.0,138.7,133.7,132.8$, 129.7, 129.4, 118.8, 118.3, 110.3, 85.4, 70.7, 69.9, 63.8, 58.0, 32.1, 31.9, 28.2, 27.8, 26.4, 22.7, 22.2, 22.1, 21.9. MS (ESI): Calcd for $\mathrm{C}_{25} \mathrm{H}_{34} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 590.14917: Found: 590.14721 $\left(\mathrm{C}_{25} \mathrm{H}_{34} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Compound 3k

Yield: $78 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.48$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3389,3293,3062,2912,2849$, $1750,1712,1586,1498,1449,1406,1316,1281,1220,1116$, 1061, $929,802,743 \mathrm{~cm}^{-1} ;{ }^{1} \mathbf{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.62(\mathrm{~s}, 1 \mathrm{H}), 7.24-7.21(\mathrm{~m}, 1 \mathrm{H}), 6.99(\mathrm{~d}, J=14 \mathrm{~Hz}, 1 \mathrm{H}), 6.64$
$(\mathrm{d}, J=5 \mathrm{~Hz}, 1 \mathrm{H}), 6.43(\mathrm{t}, J=5 \mathrm{~Hz}, 1 \mathrm{H}), 6.15-6.11(\mathrm{~m}, 1 \mathrm{H})$, $5.94(\mathrm{~s}, 1 \mathrm{H}), 5.08-4.83(\mathrm{~m}, 2 \mathrm{H}), 4.23-4.09(\mathrm{~m}, 5 \mathrm{H}), 2.98(\mathrm{~s}$, $1 \mathrm{H}), 2.55(\mathrm{~d}, J=16.5 \mathrm{~Hz}, 1 \mathrm{H}), 1.98-1.74(\mathrm{~m}, 12 \mathrm{H}), 1.29-1.14$ (m, 6H). ${ }^{13}$ C NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.2,154.6$, $147.2,146.1,138.8,133.4,131.9,129.5,128.5,118.9,112.9$, $85.5,64.2,63.2,62.6,62.1,40.3,39.6,38.9,38.8,36.9,35.1$, 34.5, 28.0, 27.9, 14.6, 14.5. MS (ESI): Calcd for $\mathrm{C}_{27} \mathrm{H}_{34} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}: \quad$ 614.14917: Found: 614.14694 $\left(\mathrm{C}_{27} \mathrm{H}_{34} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Compound 31

Yield: $62 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.51$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3382,2955,2919,2851,1736$, 1654, 1584, 1499, 1463, 1379, 1324, 1183, 1116, 1054, 853, $\mathrm{cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 8.54(\mathrm{~s}, 1 \mathrm{H}), 8.16$ (d, $J=14 \mathrm{~Hz}, 1 \mathrm{H}), 7.03-7.00(\mathrm{~m}, 1 \mathrm{H}), 6.72(\mathrm{~d}, J=9 \mathrm{~Hz}, 1 \mathrm{H})$, $6.14(\mathrm{~s}, 1 \mathrm{H}), 5.90(\mathrm{~s}, 1 \mathrm{H}), 5.07-4.82(\mathrm{~m}, 2 \mathrm{H}), 4.23-4.14(\mathrm{~m}$, $5 \mathrm{H}), 2.98(\mathrm{~s}, 1 \mathrm{H}), 2.51(\mathrm{~s}, 1 \mathrm{H}), 2.03-1.84(\mathrm{~m}, 12 \mathrm{H}), 1.31-1.14$ (m, 6H). ${ }^{13}$ C NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 154.6,150.9$, $138.7,134.7,130.1,129.0,128.2,126.2,110.6,82.5,63.1$, $62.9,62.3,40.4,39.7,38.9,36.8,35.2,34.6,31.6,28.0,26.9$, 22.7, 14.7, 14.5. MS (ESI): Calcd for $\mathrm{C}_{27} \mathrm{H}_{33} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}$ : 659.13425: Found: $659.13192\left(\mathrm{C}_{27} \mathrm{H}_{33} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}\right)$.

## Compound 3m

Yield: $72 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.51$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3380,3280,2981,2924,2853$, $1718,1601,1583,1490,1450,1412,1228,1120,1062,1004$, $928,740 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.87(\mathrm{~d}, J$ $=14.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.49(\mathrm{~d}, J=9 \mathrm{~Hz}, 1 \mathrm{H}), 7.11-7.00(\mathrm{~m}, 1 \mathrm{H}), 6.68$ $(\mathrm{s}, 1 \mathrm{H}), 6.13(\mathrm{~d}, J=5 \mathrm{~Hz}, 1 \mathrm{H}), 5.92(\mathrm{~s}, 1 \mathrm{H}), 5.07-5.00(\mathrm{~m}, 1 \mathrm{H})$, $4.86(\mathrm{~s}, 1 \mathrm{H}), 4.44-4.38(\mathrm{~m}, 1 \mathrm{H}), 4.24-4.14(\mathrm{~m}, 4 \mathrm{H}), 2.98(\mathrm{~s}$, $1 \mathrm{H}), 2.53(\mathrm{~d}, J=17.5 \mathrm{~Hz}, 1 \mathrm{H}), 1.99-1.76(\mathrm{~m}, 12 \mathrm{H}), 1.33-1.12$ $(\mathrm{m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.4,154.8$, $148.4,136.1,135.8,134.0,131.1,128.2,127.0,126.8,120.5$, $111.6,83.7,63.1,62.8,62.7,62.2,40.2,39.7,38.9,36.8,35.1$, 34.6, 29.7, 29.4, 28.0, 27.8, 14.6, 14.5. MS (ESI): Calcd for $\mathrm{C}_{28} \mathrm{H}_{33} \quad \mathrm{~F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}: ~ 682.13655$; Found: $682.13652\left(\mathrm{C}_{28} \mathrm{H}_{33}\right.$ $\mathrm{F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ ).

## Compound 3n

Yield: $80 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.46 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3297,3032,2920,2856,1736$, 1601, 1498, 1453, 1400, 1314, 1280, 1214, 1124, 1046, 1014, 848, 749, 697, $648 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ $7.62(\mathrm{~s}, 1 \mathrm{H}), 7.22(\mathrm{brs}, 1 \mathrm{H}), 7.11$ (brs, 1H), 6.74-6.64 (m, 1H), $6.43(\mathrm{t}, J=11.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.07-5.94(\mathrm{~m}, 2 \mathrm{H}), 5.06-4.88(\mathrm{~m}, 4 \mathrm{H})$, $4.07(\mathrm{~s}, 1 \mathrm{H}), 2.97(\mathrm{~s}, 1 \mathrm{H}), 2.57(\mathrm{~s}, 1 \mathrm{H}), 1.98-1.83(\mathrm{~m}, 1 \mathrm{H}), 1.25-$ 1.16 (m, 12H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.1$, $154.5,146.2,138.9,133.9,131.8,129.7,128.7,118.9,114.7$, $112.5,85.4,70.4,69.8,63.9,63.1,40.3,39.7,38.8,36.9,35.1$, 34.5, 28.0, 27.9, 22.1, 21.9. MS (ESI): Calcd for $\mathrm{C}_{29} \mathrm{H}_{38} \mathrm{IN}_{3} \mathrm{NaO}_{4}: \quad 642.18047$; Found: 642.18722 $\left(\mathrm{C}_{29} \mathrm{H}_{38} \mathrm{IN}_{3} \mathrm{NaO}_{4}\right)$.

Yield: $64 \%$ as yellow viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.54$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3389,3285,3059,2990,2926$, 2850, 1718, 1583, 1492, 1443, 1410, 1380, 1281, 1227, 1170, $1120,1059,1014,928,741,689 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR $(500 \mathrm{MHz}$, $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 8.53(\mathrm{~s}, 1 \mathrm{H}), 8.16(\mathrm{~d}, J=15 \mathrm{~Hz}, 1 \mathrm{H}), 7.15-$ $7.04(\mathrm{~m}, 1 \mathrm{H}), 6.72(\mathrm{~d}, J=9 \mathrm{~Hz}, 1 \mathrm{H}), 6.09-6.04(\mathrm{~m}, 1 \mathrm{H}), 5.89$ $(\mathrm{s}, 1 \mathrm{H}), 5.06-4.83(\mathrm{~m}, 5 \mathrm{H}), 2.97(\mathrm{~s}, 1 \mathrm{H}), 2.61(\mathrm{~s}, 1 \mathrm{H}), 1.98-1.42$ $(\mathrm{m}, 12 \mathrm{H}), 1.30-1.11(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 156.4,154.1,150.9,148.1,138.7,134.8,129.0$, $128.2,126.2,110.7,82.4,70.4,70.1,63.0,40.4,39.7,38.8$, 36.8, 35.2, 34.6, 29.3, 28.0, 27.8, 26.9, 22.1, 22.0. MS (ESI): Calcd for $\mathrm{C}_{29} \mathrm{H}_{37} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}$ : 687.16555: Found: 687.16336 $\left(\mathrm{C}_{29} \mathrm{H}_{37} \mathrm{IN}_{4} \mathrm{O}_{6} \mathrm{Na}\right)$.

## Compound 3p

Yield: $64 \%$ as yellow viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.46 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3378,3281,3059,3027,2920$, 2858, 1719, 1580, 1489, 1449, 1400, 1311, 1281, 1050, 1000, $743 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.83(\mathrm{~s}, 1 \mathrm{H})$, 7.35-7.29 (m, 11H), 6.96-6.94 (m, 1H), 6.65-6.63 (m, IH), 6.28$6.24(\mathrm{~m}, 1 \mathrm{H}), 5.83(\mathrm{brs}, 1 \mathrm{H}), 5.29-4.99(\mathrm{~m}, 6 \mathrm{H}), 4.40-4.37(\mathrm{~m}$, 1 H ), 2.93 (brs, 1 H ), 2.49 ( $\mathrm{s}, 1 \mathrm{H}$ ), 2.30 (brs, 1 H ), 1.97-1.66 (m, $11 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.2,154.4$, $148.4,135.8,135.4,134.1,128.6,128.5,128.2,111.5,83.7$, $68.4,67.9,63.0,62.8,40.3,40.1,39.5,38.7,36.7,35.1,34.6$, 34.1, 31.9, 29.7, 27.7. MS (ESI): Calcd for $\mathrm{C}_{38} \mathrm{H}_{37} \mathrm{~F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 806.16785: Found: $806.16628\left(\mathrm{C}_{38} \mathrm{H}_{37} \mathrm{~F}_{3} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

Diethyl 1-(-2-cycloheptylidene-5-(2-iodophenylamino) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3q)
Yield: $67 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.40$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3384,3295,3062,2979$, $2928,2855,1745,1710,1586,1500,1409,1228,1124,1061$, 1008, $743 \mathrm{~cm}^{-1} ;{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 7.65(\mathrm{~s}$, $1 \mathrm{H}), 7.24(\mathrm{brs}, 1 \mathrm{H}), 7.07(\mathrm{~s}, 1 \mathrm{H}), 6.65(\mathrm{~d}, J=10 \mathrm{~Hz}, 1 \mathrm{H}), 6.48$ (d, $J=11 \mathrm{~Hz}, 1 \mathrm{H}), 6.25(\mathrm{brs}, 1 \mathrm{H}), 5.98(\mathrm{~s}, 1 \mathrm{H}), 5.11-4.70(\mathrm{~m}$, $2 \mathrm{H}), 4.25-4.11(\mathrm{~m}, 5 \mathrm{H}), 2.49(\mathrm{~s}, 2 \mathrm{H}), 2.23(\mathrm{~s}, 2 \mathrm{H}), 1.85-1.14$ (m, 14H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.4,155.1$, $146.0,140.4,138.7,135.0,134.1,131.9,129.4,118.8,112.3$, 85.4, 64.9, 63.3, 62.7, 62.0, 32.5, 32.3, 29.7, 29.1, 27.8, 27.4, 26.8, 14.4. MS (ESI): Calcd for $\mathrm{C}_{24} \mathrm{H}_{32} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 576.13352; Found: $576.13131\left(\mathrm{C}_{24} \mathrm{H}_{32} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

Diethyl 1-(-2-cyclopentylidene-5-(2-iodophenylamino) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3r)
Yield: $68 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.37$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3388,3289,2978,2955,2926$, $2869,1714,1587,1499,1453,1385,1315,1280,1231,1180$, $1107,1037,956,743 \mathrm{~cm}^{-1} ;{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.60(\mathrm{~s}, 1 \mathrm{H}), 7.20($ brs, 1 H$), 7.08($ brs, 1 H$), 6.43(\mathrm{~d}, J=10$ $\mathrm{Hz}, 2 \mathrm{H}), 6.18$ (brs, 1 H ), 5.93 (s, 1H), 5.05 (m, 2H), 4.17 (m, $5 \mathrm{H}), 2.43(\mathrm{~s}, 2 \mathrm{H}), 2.15-2.06(\mathrm{~m}, 2 \mathrm{H}), 1.75-1.57(\mathrm{~m}, 4 \mathrm{H}), 1.30-$ $1.10(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.7$, $155.6,146.1,140.7,138.8,134.9,131.8,129.5,118.9,112.9$, $85.4,66.2,65.0,63.3,62.7,31.9,31.6,30.5,26.7,26.4,14.5$.

## Compound 3o

MS (ESI): Calcd for $\mathrm{C}_{22} \mathrm{H}_{28} \quad \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 548.10222; Found: $548.09994\left(\mathrm{C}_{22} \mathrm{H}_{28} \mathrm{IN}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Diethyl 1--2-(2-iodophenylamino)-5-(2H-pyran-4 (3H, 5H, 6H)-

 ylidene) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (3s)Yield: $59 \%$ as pale yellow viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.48 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3369,3291,3048$, 2980, 2931, 2872, 1711, 1601, 1491, 1452, 1414, 1381, , 1281, $1228,1171,1123,1009,930,750 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR ( 500 MHz , $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.64(\mathrm{~s}, 1 \mathrm{H}), 7.22(\mathrm{~s}, 1 \mathrm{H}), 6.96(\mathrm{~s}, 1 \mathrm{H}), 6.80(\mathrm{~s}$, $1 \mathrm{H}), 6.61(\mathrm{~d}, J=5 \mathrm{~Hz}, 1 \mathrm{H}), 6.46-6.34(\mathrm{~m}, 1 \mathrm{H}), 6.03(\mathrm{~s}, 1 \mathrm{H})$, $5.11-4.92(\mathrm{~m}, 2 \mathrm{H}), 4.24-4.18(\mathrm{~m}, 5 \mathrm{H}), 3.83-3.59(\mathrm{~m}, 4 \mathrm{H}), 2.51-$ 2.21(m, 6H), 1.29-1.11(m, 8H). ${ }^{13}$ C NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 156.8,154.9,145.9,145.3,138.9,137.5,135.8,133.1$, $127.3,119.1,112.7,85.5,68.5,68.2,63.6,63.3,62.7,62.1$, 31.9, 31.4, 14.4. MS (ESI): Calcd for $\mathrm{C}_{22} \mathrm{H}_{28} \mathrm{~N}_{3} \mathrm{O}_{5} \mathrm{Na}$ : 564.09713; Found: $564.01004\left(\mathrm{C}_{22} \mathrm{H}_{28} \mathrm{IN}_{3} \mathrm{O}_{5} \mathrm{Na}\right)$.

General procedure for the Lewis acid catalyzed reaction of pentafulvene derived bicyclic hydrazines with 2-iodophenol

A mixture of pentafulvene derived diazabicyclic olefin (3.0 eqiuv.), $o$-iodoaniline ( 1.0 equiv.), AgOTf ( $3 \mathrm{~mol} \%$ ) and $\mathrm{Na}_{2} \mathrm{CO}_{3}$ ( 1.5 equiv) were weighed in a schlenk tube and degassed for 10 minutes. Dry acetonitrile ( 2 ml ) was added and the reaction mixture was purged with argon and allowed to stir at room temperature for 2 hours. The solvent was evaporated in vacuo and the residue on silica gel (100-200 mesh) column chromatography yielded trans-3,4-disubstituted alkylidene cyclopentene.

Diethyl 1-2-(2-iodophenoxy)-5-(propan-2-ylidene) cyclopent-3-enyl)hydrazine-1,2-dicarboxylate (5a)
Yield: $55 \%$ as yellow viscous liquid $\mathrm{R}_{f}=0.60$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\text {max }}$ : 3357, 3064, 2958, 2921, 2854, $1715,1578,1467,1411,1379,1307,1280,1236,1167,1122$, $1058,752 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.75(\mathrm{~d}$, $J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.30-7.27(\mathrm{~m}, 1 \mathrm{H}), 6.93-6.87(\mathrm{~m}, 2 \mathrm{H}), 6.73-$ $6.68(\mathrm{~m}, 2 \mathrm{H}), 5.95(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.74(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H})$, $5.48(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.12-4.02(\mathrm{~m}, 4 \mathrm{H}), 1.95-1.84(\mathrm{~m}, 3 \mathrm{H})$, $1.84(\mathrm{~s}, 3 \mathrm{H}), 1.24-1.11(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 156.1,155.9,139.3,135.8,133.3,132.6,129.6,128.1$, 123.0, 113.0, 80.6, 62.4, 61.2, 57.8, 21.7, 21.1, 14.5. HRMS (ESI): Calcd for $\mathrm{C}_{20} \mathrm{H}_{25} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}$ [M+Na]: 523.07058; Found: 523.07117.

## Compound 5b

Yield: $47 \%$ as colourless viscous liquid; $\mathrm{R}_{f}=0.67$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }: 3355,3063,2915$, 2852, 1715, 1577, 1467, 1410, 1379, 1303, 1219, 1124, 1058, 1022, 73, 873, $746 \mathrm{~cm}^{-1}$. ${ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ 7.77-7.73 (m, 1H), 7.31-7.28 (m, 1H), 6.93-6.88 (m, 1H), 6.85 $(\mathrm{s}, 1 \mathrm{H}), 6.73-6.70(\mathrm{~m}, 2 \mathrm{H}), 5.93(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.74(\mathrm{~d}, J=$ $7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.49(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.15-3.95(\mathrm{~m}, 4 \mathrm{H}), 2.89(\mathrm{~d}$, $J=15.5 \mathrm{~Hz}, 2 \mathrm{H}), 2.43(\mathrm{~d}, J=12 \mathrm{~Hz}, 1 \mathrm{H}), 1.97-1.72(\mathrm{~m}, 11 \mathrm{H})$, $1.24(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}), 1.08(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR (125 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 156.0,155.1,148.6,139.3,134.8,129.6$,
$129.1,127.8,126.1,123.0,113.0,80.8,62.3,61.1,57.1,40.1$, 40.0, 38.2, 37.3, 37.2, 35.1, 35.0, 28.4, 28.0, 14.6, 14.3. HRMS (ESI): Calcd for $\mathrm{C}_{27} \mathrm{H}_{33} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}$ [M+Na]: 615.13318; Found: 615.13287.

## Diisopropyl 1-(2-cyclohexylidene-5-(2-iodo-4-nitrophenoxy) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (5c)

Yield: $45 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.69$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }: 3376,3062,2921,2853,1757$, 1710, 1657, 1577, 1517, 1468, 1411, 1380, 1341, 1305, 1267, $1216,1119,1037,894,740 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 8.64(\mathrm{~d}, J=2 \mathrm{~Hz}, 1 \mathrm{H}), 8.24(\mathrm{~m}, 1 \mathrm{H}), 6.99(\mathrm{~d}, J=9.5$ $\mathrm{Hz}, 1 \mathrm{H}), 6.79(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.53(\mathrm{~s}, 1 \mathrm{H}), 5.94-5.91(\mathrm{~m}$, $1 \mathrm{H}), 5.81(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.57(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.85-4.82$ $(\mathrm{m}, 1 \mathrm{H}), 4.73-4.70(\mathrm{~m}, 1 \mathrm{H}), 2.45-2.43(\mathrm{~m}, 2 \mathrm{H}), 1.90-1.42(\mathrm{~m}$, 8 H ), 1.29-1.16 (m, 12H). ${ }^{13}$ C NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $160.9,155.1,154.8,142.2,141.9,136.3,134.8,129.5,126.9$, 125.6, 111.7, 82.0, 70.1, 68.9, 56.8, 31.9, 31.5, 27.8, 27.2, 26.4, 22.1, 22.0, 21.8. HRMS (ESI): Calcd for $\mathrm{C}_{25} \mathrm{H}_{32} \mathrm{IN}_{3} \mathrm{O}_{7} \mathrm{Na}$ [M+Na]: 636.11826; Found: 636.11866.

## Compound 5d

Yield: $51 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.69$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }$ : 3362, 2909, 2851, 1759, 1719, 1591, 1481, 1438, 1407, 1386, 1301, 1257, 1215, 1116, 1048, 875, 761, 668, 611, $556 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right.$, TMS): $\delta 8.65(\mathrm{~s}, 1 \mathrm{H}), 8.25(\mathrm{~d}, J=9.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.99(\mathrm{~d}, J=9$ $\mathrm{Hz}, 1 \mathrm{H}), 6.79(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.62(\mathrm{~s}, 1 \mathrm{H}), 5.89(\mathrm{~d}, J=5.5$ $\mathrm{Hz}, 1 \mathrm{H}), 5.78(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.58(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.14-$ $3.94(\mathrm{~m}, 4 \mathrm{H}), 2.88(\mathrm{~s}, 2 \mathrm{H}), 2.42(\mathrm{~d}, J=12 \mathrm{~Hz}, 1 \mathrm{H}), 1.98-1.80$ $(\mathrm{m}, 11 \mathrm{H}), 1.25(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}), 1.08(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 160.4,155.2,153.2,142.6$, $140.4,136.3,134.9,133.9,126.3,125.7,82.1,62.5,61.4,59.1$, 57.1, 40.1, 38.6, 37.1, 35.2, 28.3, 27.9, 14.6, 14.3, 10.4. HRMS (ESI): Calcd for $\mathrm{C}_{27} \mathrm{H}_{32} \mathrm{IN}_{3} \mathrm{O}_{7} \mathrm{Na}$ [M+Na]: 660.11826; Found: 660.11799 .

## Diisopropyl 1-(-2-(2-iodo-4-(trifluoromethyl) phenylamino)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2-

 dicarboxylate (5e)Yield: $46 \%$ as colourless viscous liquid; $\mathrm{R}_{f}=0.73$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }: 3370,2913,2850$, $1760,1719,1591,1567,1480,1439,1407,1385,1301,1256$, 1214, 1117, 1046, 972, 942, 876, 838, 803, 760, 728, 698, 667 $\mathrm{cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 8.43(\mathrm{~d}, J=1.5 \mathrm{H}$ $\mathrm{z}, 1 \mathrm{H}), 8.01-7.99(\mathrm{~m}, 1 \mathrm{H}), 6.93(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.76(\mathrm{~s}$, $2 \mathrm{H}), 5.91(\mathrm{~d}, J=6 \mathrm{~Hz}, 1 \mathrm{H}), 5.76(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.56(\mathrm{~d}, J$ $=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.12-3.94(\mathrm{~m}, 4 \mathrm{H}), 3.89(\mathrm{~s}, 3 \mathrm{H}), 2.89(\mathrm{~s}, 2 \mathrm{H}), 2.42$ $(\mathrm{d}, J=11.5 \mathrm{~Hz}, 1 \mathrm{H}), 1.97-1.72(\mathrm{~m}, 1 \mathrm{H}), 1.24(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H})$, 1.08 ( $\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}$ ). ${ }^{13} \mathbf{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ $165.1,159.1,156.1,155.2,140.9,140.4,131.7,125.8,124.9$, $124.7,114.6,112.0,81.1,62.5,61.4,52.1,40.1,37.2,35.2$, 28.4, 28.0, 14.7, 14.4. HRMS (ESI): Calcd for $\mathrm{C}_{29} \mathrm{H}_{35} \mathrm{IN}_{2} \mathrm{O}_{7} \mathrm{Na}$ [M+Na]: 673.13866; Found: 673.13855.

## Diethyl 1-(-2-cyclohexylidene-5-(2-iodophenoxy) cyclopent-3enyl) hydrazine-1,2-dicarboxylate (5f)

Yield: $63 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.67$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }: 3385,3052,2925,2855,1763$, 1718, 1596, 1478, 1462, 1409, 1379, 1309, 1277, 1218, 1129 , 1097, 1065, 924, 838, $752 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right.$, TMS): $\delta 7.74(\mathrm{~d}, J=8 \mathrm{~Hz}, 1 \mathrm{H}), 7.29-7.26(\mathrm{~m}, 1 \mathrm{H}), 6.91(\mathrm{~d}, J=$ $8.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.85(\mathrm{~s}, 1 \mathrm{H}), 6.73-6.69(\mathrm{~m}, 2 \mathrm{H}), 5.95(\mathrm{~d}, J=5.5$ $\mathrm{Hz}, 1 \mathrm{H}), 5.76(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.48(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.11-$ $4.01(\mathrm{~m}, 4 \mathrm{H}), 2.43-2.35(\mathrm{~m}, 2 \mathrm{H}), 2.16-2.12(\mathrm{~m}, 1 \mathrm{H}), 1.88-1.42$ $(\mathrm{m}, 7 \mathrm{H}), 1.23(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}), 1.10(\mathrm{t}, J=7 \mathrm{~Hz}, 3 \mathrm{H}) .{ }^{13} \mathrm{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.0,155.3,140.9,139.4$, $135.3,129.9,129.7,128.3,123.5,113.0,80.6,62.4,61.2,58.4$, 31.9, 31.5, 27.8, 27.2, 26.5, 14.6, 14.4. HRMS (ESI): Calcd for $\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}[\mathrm{M}+\mathrm{Na}]: 563.10188$; Found: 563.10076.

## Compound 5g

Yield: $27 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.73$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }: 3365,3062,3029,2979,2908$, 2849, 1757, 1710, 1660, 1595, 1555, 1473, 1404, 1385, 1302, $1241,1218,1179,1110,1045,974,955,921,876,808,760$, $739,699,664,640,603,555 . \mathrm{cm}^{-1} .{ }^{1} \mathbf{H} \mathbf{N M R}(500 \mathrm{MHz}$, $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.97(\mathrm{~s}, 1 \mathrm{H}), 7.53-7.48(\mathrm{~m}, 3 \mathrm{H}), 7.42-7.39(\mathrm{~m}$, $3 \mathrm{H}), 6.99(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.76-6.72(\mathrm{~m}, 2 \mathrm{H}), 5.95(\mathrm{~d}, J=$ $5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.78(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.52(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H})$, 4.88-4.84 (m, 1H), 4.74-4.69 (m, 1H), 2.94-2.89 (m, 3H), 2.43 $(\mathrm{d}, J=12 \mathrm{~Hz}, 1 \mathrm{H}), 1.96-1.73(\mathrm{~m}, 10 \mathrm{H}), 1.26-1.22(\mathrm{~m}, 12 \mathrm{H})$. ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 155.4,154.8,148.5$, $139.2,137.8,136.4,134.8,128.8,128.2,127.9,127.2,126.7$, $126.3,113.0,81.2,69.9,68.5,56.9,40.1,38.3,37.3,35.1,35.0$, 28.4, 28.0, 22.1, 22.0. HRMS (ESI): Calcd for $\mathrm{C}_{35} \mathrm{H}_{41} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}$ [M+Na]:719.19579: Found: 719.19532.

## Dibenzyl 1-(-2-cyclohexylidene-5-(2-iodo-4-nitrophenoxy) cyclopent-3enyl)hydrazine-1,2-dicarboxylate (5h)

Yield: $42 \%$ as yellow viscous liquid $\mathrm{R}_{f}=0.67$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }$ : 3360, 2910, 2854, 1759, 1715, 1598, 1479, 1438, 1405, 1387, 1298, 1257, 1215, 1118, 1045, $924,836,754 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 8.45$ (d, $J=2 \mathrm{~Hz}, 1 \mathrm{H}), 8.14(\mathrm{~m}, 1 \mathrm{H}), 7.32-7.14(\mathrm{~m}, 10 \mathrm{H}), 6.89(\mathrm{~d}, J$ $=9 \mathrm{~Hz}, 1 \mathrm{H}), 6.76-6.74(\mathrm{~m}, 2 \mathrm{H}), 5.90(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.82$ (d, $J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.52(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.14-5.06(\mathrm{~m}, 4 \mathrm{H})$, 2.41-2.37 (m, 2H), 2.10-2.05 (m, 1H), 1.89-1.88 (m, 1H), 1.67$1.62(\mathrm{~m}, 3 \mathrm{H}), 1.44-1.39(\mathrm{~m}, 3 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 160.6,155.4,155.0,142.4,142.2,136.4,136.3,135.7$, $134.9,129.9,129.6,129.1,128.5,128.4,128.3,128.2,128.1$, 127.7 (2), 126.8, 125.5, 111.5, 81.8, 68.0, 66.9, 57.4, 31.9, 31.4, 27.7, 27.1, 26.4. HRMS (ESI): Calcd for $\mathrm{C}_{33} \mathrm{H}_{32} \mathrm{IN}_{3} \mathrm{O}_{7} \mathrm{Na}$ [M+Na]: 732.11826; Found: 732.11755.

## Compound 5i

Yield: $47 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.67$ (hexane/ethyl acetate; 7:3). IR (Neat) $v_{\max }: 3366,2920,2854,1760,1718$, 1654, 1592, 1483, 1446, 1406, 1300, 1258, 1214, 1117, 1046, $756,698,611 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 8.35$
( $\mathrm{s}, 1 \mathrm{H}$ ), $7.97(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.32-7.21(\mathrm{~m}, 10 \mathrm{H}), 6.99(\mathrm{~s}$, $1 \mathrm{H}), 6.89(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.71(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.89(\mathrm{~d}$, $J=6 \mathrm{~Hz}, 1 \mathrm{H}), 5.80(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.55(\mathrm{~d}, J=6.5 \mathrm{~Hz}$, $1 \mathrm{H}), 5.16-5.03(\mathrm{~m}, 4 \mathrm{H}), 3.89(\mathrm{~s}, 3 \mathrm{H}), 2.91-2.83(\mathrm{~m}, 2 \mathrm{H}), 2.44$ $(\mathrm{d}, J=11.5 \mathrm{~Hz}, 1 \mathrm{H}), 1.95-1.68(\mathrm{~m}, 11 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( 125 MHz , $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): ~ \delta 165.1,155.8,155.0,149.4,140.9,140.4$, $136.4,135.8,135.5,131.5,128.4,128.3,128.1,127.9,127.8$, $127.5,127.4,126.8,125.5,124.8,111.8,81.0,67.9,66.7,57.2$, 52.1, 40.0, 37.9, 37.1, 35.1(2), 28.3, 27.9. HRMS (ESI): Calcd for $\mathrm{C}_{39} \mathrm{H}_{39} \mathrm{IN}_{2} \mathrm{O}_{7} \mathrm{Na}[\mathrm{M}+\mathrm{Na}]$ : 797.16996; Found: 797.16933.

Dibenzyl 1-(-2-cyclohexylidene-5-(3-iodobiphenyl-4-yloxy) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (5j)
Yield: $40 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.64$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\text {max }}: 3382,3053,2925,2855,1761$, 1715, 1596, 1476, 1461, 1408, 1378, 1310, 1279, 1217, 1130, 1097, 1066, $924,839 \mathrm{~cm}^{-1}$; ${ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.9(\mathrm{~s}, 1 \mathrm{H}), 7.49-7.19(\mathrm{~m}, 16 \mathrm{H}), 7.05(\mathrm{~s}, 1 \mathrm{H}), 6.94(\mathrm{~d}, J=8.5$ $\mathrm{Hz}, 1 \mathrm{H}), 6.70(\mathrm{~d}, J=6 \mathrm{~Hz}, 1 \mathrm{H}), 5.97(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H})$, $5.81(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.50(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.11-4.99(\mathrm{~m}$, $4 \mathrm{H}), 2.45-2.38(\mathrm{~m}, 3 \mathrm{H}), 2.11-2.07(\mathrm{~m}, 1 \mathrm{H}), 1.89-1.85(\mathrm{~m}, 1 \mathrm{H})$, 1.64-1.41(m, 5H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ $155.9,155.4,155.2,141.2,139.1,137.8,136.5,136.4,136.0$, $135.5,129.0,128.8$ (2), 128.4, 128.3(2), 128.2 (2), 128.1, 128.0, 127.9, 127.7, 127.5, 127.3 (2), 126.7, 113.1, 80.9, 67.8, 66.7, 57.6, 31.9, 31.4, 29.7, 27.7, 27.2, 22.7, 14.2. HRMS (ESI): Calcd for $\mathrm{C}_{39} \mathrm{H}_{37} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}$ [M+Na]: 763.16448: Found: 763.16501.

## Compound 5k

Yield: $28 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.71$ (hexane/ethyl acetate $=7: 3$ ). IR (Neat) $v_{\max }: 3368,3063,3032,2960,2960$, 2908, 2848, 1762, 91, 1467, 1716, 1609, 1578, 1491, 1467, $1444,1407,1359,1300,1262,1238,1211,1100,1050,871$, $801,748,697,657,602,556 \mathrm{~cm}^{-1} ;{ }^{1} \mathbf{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 7.69(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.33-7.21(\mathrm{~m}, 11 \mathrm{H}), 7.10(\mathrm{~s}$, $1 \mathrm{H}), 6.90(\mathrm{~d}, J=8 \mathrm{~Hz}, 1 \mathrm{H}), 6.71-6.67(\mathrm{~m}, 2 \mathrm{H}), 5.92(\mathrm{~d}, J=6$ $\mathrm{Hz}, 1 \mathrm{H}), 5.79(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.49(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.16-$ $5.04(\mathrm{~m}, 4 \mathrm{H}), 3.04-2.83(\mathrm{~m}, 3 \mathrm{H}), 2.46-2.43(\mathrm{~m}, 1 \mathrm{H}), 1.95-1.66$ (m, 10H). ${ }^{13}$ C NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 156.0,155.9$, $155.1,148.8,139.3,136.5,136.1,135.0,128.4(3), 128.3,128.2$, $128.1,128.0,127.9,127.8,127.7,127.6,123.1,113.1,80.7$, $68.1,67.8,67.7,66.7,57.4,40.0,38.0,37.2,37.1,35.1,35.0$, 28.4, 27.9. HRMS (ESI): Calcd for $\mathrm{C}_{37} \mathrm{H}_{37} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}[\mathrm{M}+\mathrm{Na}]:$ 739.16448: Found: 739.16400.

Diisopropyl 1-(-2-cyclohexylidene-5-(2-iodophenoxy) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (51)
Yield: $56 \%$ as white solid; $\mathrm{Mp}: 138^{\circ} \mathrm{C} ; \mathrm{R}_{f}=0.73$ (hexane/ethyl acetate $=7: 3$ ). IR (Neat) $v_{\text {max }}: 3367,3066,2977,2926,2853$, 1756, 1710, 1577, 1468, 1443, 1404, 1382, 1300, 1220, 1177, $1110,1043,961,936,874,854,806,749 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR (300 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): 7.73(\mathrm{~d}, J=8 \mathrm{~Hz}, 1 \mathrm{H}), 7.30-7.26(\mathrm{~m}, 1 \mathrm{H})$, $6.92(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.73-6.69(\mathrm{~m}, 3 \mathrm{H}), 5.95(\mathrm{~d}, J=6 \mathrm{~Hz}$, $1 \mathrm{H}), 5.77(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.47(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.85-4.71$ (m, 2H), 2.64-2.59 (m, 1H), 2.45-2.34 (m, 2H), 2.15-2.10 (m,
$1 \mathrm{H}), 1.87(\mathrm{~d}, J=6 \mathrm{~Hz}, 1 \mathrm{H}), 1.68-1.38(\mathrm{~m}, 4 \mathrm{H}), 1.23-0.95(\mathrm{~m}$, 12H). ${ }^{13} \mathbf{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ 155.4, 155.1, $140.7,139.3,135.2,130.1,129.6,129.5,128.4,122.9,113.0$, 80.6, 69.9, 68.6, 57.0, 31.8, 31.4, 27.8, 27.3, 26.5, 22.2, 22.0. HRMS (ESI): Calcd for $\mathrm{C}_{25} \mathrm{H}_{33} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}$ [M+Na]: 591.13318: Found: 591.13366.

## Compound 5m

Yield: $49 \%$ as white solid; Mp: $154{ }^{\circ} \mathrm{C} ; \mathrm{R}_{f}=0.69$ (hexane/ethyl acetate $=7: 3$ ). IR (Neat) $v_{\text {max }}: 3366,3065,2979,2908,2850$, 1757, 1709, 1661, 1577, 1468, 1404, 1381, 1301, 1217, 1178, $1110,1046,1025,974,942,870,806,750 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR (500 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.73$ (d, $\left.J=7.5 \mathrm{~Hz}, 1 \mathrm{H}\right), 7.31-7.26(\mathrm{~m}$, $1 \mathrm{H}), 6.93(\mathrm{~d}, J=8 \mathrm{~Hz}, 1 \mathrm{H}), 6.75-6.69(\mathrm{~m}, 3 \mathrm{H}), 5.93(\mathrm{~d}, J=6.5$ $\mathrm{Hz}, 1 \mathrm{H}), 5.75(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 5.48(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.86-$ $4.69(\mathrm{~m}, 2 \mathrm{H}), 2.93-2.87(\mathrm{~m}, 2 \mathrm{H}), 2.42(\mathrm{~d}, J=12 \mathrm{~Hz}, 1 \mathrm{H}), 1.97-$ $1.79(\mathrm{~m}, 11 \mathrm{H}), 1.25-0.94(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( 125 MHz , $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 155.4,154.8,148.3,139.3,134.7,129.6$, $128.0,126.3,113.0,80.9,69.9,68.5,56.9,40.0(2), 38.3,37.3$, 35.0(2), 28.4, 28.0, 22.1, 22.0. HRMS (ESI): Calcd for $\mathrm{C}_{29} \mathrm{H}_{37} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}[\mathrm{M}+\mathrm{Na}]: 643.16448$; Found: 643.16521 .

Dibenzyl 1-(-2-cyclohexylidene-5-(2-iodophenoxy) cyclopent-3enyl) hydrazine-1,2-dicarboxylate (5n)

Yield: $52 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.67$ (hexane/ethyl acetate, 7:3). IR (Neat) $v_{\max }: 3366,3064,3032,2925,2852$, 1762, 1716, 1660, 1578, 1491, 1467, 1443, 1407, 1302, 1237, $1211,1125,1050,1023,974,928,875,851,806,748,697 \mathrm{~cm}^{-}$
${ }^{1} .{ }^{1} \mathbf{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.67(\mathrm{~d}, J=7.5 \mathrm{~Hz}$, $1 \mathrm{H}), 7.31-7.19(\mathrm{~m}, 12 \mathrm{H}), 7.04(\mathrm{~s}, 1 \mathrm{H}), 6.89(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H})$, 6.70-6.67 (m, 2H), $5.94(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.79(\mathrm{~d}, J=7.5 \mathrm{~Hz}$, $1 \mathrm{H}), 5.47(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.12-4.97(\mathrm{~m}, 4 \mathrm{H}), 2.42-2.32(\mathrm{~m}$, 2H), 2.10-2.08 (m, 1H), 1.63-1.40 (m, 7H). ${ }^{13}$ C NMR (125 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 155.9,155.2,141.1,139.4,136.5,136.1$, $135.4,129.7,129.6,128.6,128.4,128.3$ (2), 128.2, 127.9 (2), $127.7,127.5,127.4,123.1,113.1,80.6,67.8,66.7,57.6,31.4$, 29.7, 29.5, 29.4, 27.7, 27.2. HRMS (ESI): Calcd for $\mathrm{C}_{33} \mathrm{H}_{33} \mathrm{IN}_{2} \mathrm{O}_{5} \mathrm{Na}[\mathrm{M}+\mathrm{Na}]: 687.13318$; Found: 687.13368.

General procedure for the Lewis acid catalyzed reaction of
pentafulvene derived bicyclic hydrazines with 2 -
iodobenzenethiol
A mixture of pentafulvene derived diazabicyclic olefin (2.0 eqiuv.), 2-iodobenzenethiol (1.0 equiv.) and $\mathrm{Zn}(\mathrm{OTf})_{2}$ (5 $\mathrm{mol} \%)$ were weighed in a Schlenk tube and degassed for 10 minutes. Dry THF ( 2 ml ) was added and the reaction mixture was purged with argon and allowed to stir at room temperature for 2 hours. The solvent was evaporated in vacuo and the residue on silica gel (100-200 mesh) column chromatography yielded trans-3,4-disubstituted alkylidenecyclopentene.

## Diethyl 1-(-2-cyclohexylidene-5-(2-iodophenylthio) cyclopent-3-enyl) hydrazine-1,2dicarboxylate (7a)

Yield: $76 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.39$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3728,3294,3058,2927,2853$, $1709,1562,1440,1410,1301,1225,1115,1060,1013,933$,

863, $750,558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.79$ (brs, $1 \mathrm{H}), 7.32-7.27(\mathrm{~m}, 2 \mathrm{H}), 6.85(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 6.55(\mathrm{~d}, J=6$ $\mathrm{Hz}, 1 \mathrm{H})$, 6.26-6.16 (m, 1H), 5.92-5.87 (m, 1H), 5.44-5.26 (m, $1 \mathrm{H}), 4.78($ brs, 1 H$), 4.20-4.14(\mathrm{~m}, 4 \mathrm{H}), 2.31-2.28(\mathrm{~m}, 2 \mathrm{H})$, 2.16-2.08 (m, 2H), 1.57-1.43 (m, 6H), 1.27-1.25 (m, 6H). ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 156.5,154.6,140.8,139.2,133.2$, $132.5,130.5,128.9,128.5,128.1,127.1,126.7,81.4,65.0$, 62.6, 62.0, 56.0, 31.9, 31.4, 29.6, 28.1, 27.9, 26.3, 14.5. HRMS (ESI): calcd for $\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 579.07904; found: 579.07955.

## Diisopropyl 1-(-2-cyclohexylidene-5-(2-iodophenylthio) cyclopent-3-enyl) hydrazine-1,2 dicarboxylate (7b)

Yield: $60 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.48$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3727,3292,2925,2855,2309$, 1704, 1608, 1503, 1446, 1392, 1299, 1174, 1109, 1032, 754, $670,613,560 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.84(\mathrm{~d}, J=$ $8 \mathrm{~Hz}, 1 \mathrm{H}), 7.42(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.30-7.27(\mathrm{~m}, 2 \mathrm{H}), 6.90-$ $6.83(\mathrm{~m}, 1 \mathrm{H}), 6.50(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.98-5.92(\mathrm{~m}, 2 \mathrm{H}), 5.29$ $(\mathrm{m}, 1 \mathrm{H}), 5.00-4.90(\mathrm{~m}, 2 \mathrm{H}), 4.75(\mathrm{brs}, 1 \mathrm{H}), 2.29-2.11(\mathrm{~m}, 4 \mathrm{H})$, $1.63-1.57(\mathrm{~m}, 6 \mathrm{H}), 1.29-1.22(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( 125 MHz , $\left.\mathrm{CDCl}_{3}\right): \delta 155.7,154.8,139.8,139.3,134.5,133.0,131.3$, 130.6, 129.1, 128.6, 128.1, 127.6, 83.5, 70.1, 69.4, 62.8, 32.9, 32.0, 31.6, 28.2, 27.9, 26.9, 26.4, 22.2, 22.0. HRMS (ESI): calcd for $\mathrm{C}_{25} \mathrm{H}_{33} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 607.11034; found: 607.11096.

## Compound 7e

Yield: $58 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.43$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3297,3059,2976,2912,2851$, $1710,1565,1443,1411,1299,1222,1172,1110,1061,1015$, 867, $749,558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.85-7.79$ $(\mathrm{m}, 1 \mathrm{H}), 7.32-7.28(\mathrm{~m}, 2 \mathrm{H}), 6.90-6.85(\mathrm{~m}, 1 \mathrm{H}), 6.54(\mathrm{~d}, J=5.5$ $\mathrm{Hz}, 1 \mathrm{H}), 6.12-5.85(\mathrm{~m}, 2 \mathrm{H}), 5.45-5.25(\mathrm{~m}, 1 \mathrm{H}), 4.76$ (brs, 1 H$)$, 4.24-4.19 (m, 4H), $2.92(\mathrm{~s}, 1 \mathrm{H}), 2.56(\mathrm{brs}, 1 \mathrm{H}), 1.96-1.72(\mathrm{~m}$, $12 \mathrm{H}), 1.29-1.26(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $156.2,155.0,140.8,139.4,130.4,128.6,128.5,128.4,127.5$, $121.6,85.1,64.8,62.8,60.9,53.3,38.8,36.8,35.6,35.6,35.1$, 34.7, 27.8, 27.7, 27.6, 14.7, 14.6, 14.5. HRMS (ESI): calcd for $\mathrm{C}_{27} \mathrm{H}_{33} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}[\mathrm{M}+\mathrm{Na}]$ : 631.11034; found: 631.11102.

## Compound 7d

Yield: $41 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.48$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3727,3307,3060,2978,2914$, 2853, 1711, 1627, 1565, 1449, 1388, 1299, 1231, 1178, 1109, $1035,946,837,750,558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $300 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $7.81(\mathrm{~m}, 1 \mathrm{H}), 7.26-7.14(\mathrm{~m}, 2 \mathrm{H}), 6.85-6.83(\mathrm{~m}, 1 \mathrm{H}), 6.54(\mathrm{~d}, J$ $=5.1 \mathrm{~Hz}, 1 \mathrm{H}), 6.00-5.89(\mathrm{~m}, 2 \mathrm{H}), 5.43-5.27(\mathrm{~m}, 1 \mathrm{H}), 4.95(\mathrm{~m}$, $2 \mathrm{H}), 4.73($ brs, 1 H$), 2.92(\mathrm{~s}, 1 \mathrm{H}), 2.72-2.59(\mathrm{~m}, 1 \mathrm{H}), 1.95-1.82$ $(\mathrm{m}, 12 \mathrm{H}), 1.26-1.07(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR $\left(125 \mathrm{MHz}, \mathrm{CDCl}_{3}\right): \delta$ $156.7,155.5,139.7,139.3,137.7,132.9,129.0,128.5,128.2$, $126.6,125.3,81.2,70.1,69.8,64.7,55.5,38.8,36.9,35.1,34.7$, 34.5, 31.6, 28.2, 28.0, 27.8, 26.9, 22.1, 22.0, 14.2. HRMS (ESI): calcd for $\mathrm{C}_{29} \mathrm{H}_{37} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 659.14164; found: 659.14270.

Diethyl 1-(-2-cyclopentylidene-5-(2-iodophenylthio) cyclopent-3-
enyl) hydrazine-1,2-dicarboxylate (7e)
Yield: $40 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.35$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3728,3298,2925,2862,1710$, $1602,1416,1384,1304,1231,1166,1108,1060,753,666$, $612,558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.78(\mathrm{~d}, J=7.5$ $\mathrm{Hz}, 1 \mathrm{H}), 7.36(\mathrm{~d}, J=7.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.25-7.19(\mathrm{~m}, 1 \mathrm{H}), 6.84-6.81$ $(\mathrm{m}, 1 \mathrm{H}), 6.33-6.30(\mathrm{~m}, 1 \mathrm{H}), 6.11-5.82(\mathrm{~m}, 2 \mathrm{H}), 5.31-5.14(\mathrm{~m}$, $1 \mathrm{H}), 4.74$ (brs, 1 H ), 4.14-4.10 (m, 4H), 2.34-2.22 (m, 4H), 1.67-1.57 (m, 4H), 1.23-1.19 (m, 6H). ${ }^{13}$ C NMR ( 125 MHz , $\left.\mathrm{CDCl}_{3}\right): \delta 155.6,154.9,139.8,139.3,131.3,130.1,129.8$, 129.1, 128.6, 128.4, 128.0, 126.5, 83.2, 62.8, 62.4, 61.7, 55.4, 26.7, 26.4, 25.7, 24.6, 14.6, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{22} \mathrm{H}_{27} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 565.06339; found: 607.06390 .

## Diisopropyl 1-(-2-(2-iodophenylthio)-5-(propan-2-ylidene) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (7f)

Yield: $57 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.36$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3728,3336,2920,2854,2393$, 2311, 1733, 1603, 1457, 1377, 1303, 1245, 1171, 1108, 1053, $743,666,612,558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.76$ $(\mathrm{m}, 1 \mathrm{H}), 7.40-7.37(\mathrm{~m}, 2 \mathrm{H}), 6.92-6.90(\mathrm{~m}, 1 \mathrm{H}), 6.78(\mathrm{~d}, J=5.5$ $\mathrm{Hz}, 1 \mathrm{H}), 6.19(\mathrm{~d}, J=5 \mathrm{~Hz}, 1 \mathrm{H}), 5.32-5.31(\mathrm{~m}, 1 \mathrm{H}), 5.23(\mathrm{~d}, J=$ $6 \mathrm{~Hz}, 1 \mathrm{H}), 5.04-4.92(\mathrm{~m}, 2 \mathrm{H}), 4.67(\mathrm{brs}, 1 \mathrm{H}), 1.96(\mathrm{~s}, 3 \mathrm{H}), 1.87$ (s, 3H), 1.31-1.28 (m, 12H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $155.9,154.9,139.2,138.1,135.8,132.7,130.0,129.0,128.7$, $127.4,80.9,70.3,70.1,69.7,64.3,22.1,22.0,21.8,21.4$. HRMS (ESI): calcd for $\mathrm{C}_{22} \mathrm{H}_{29} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 567.07904; found: 567.07934.

Diethyl 1-(-2-cycloheptylidene-5-(2-iodophenylthio) cyclopent-3enyl) hydrazine-1,2-dicarboxylate (7g)
Yield: $64 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.4$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3729,3300,2977,2925,2857$, 2390, 2312, 1712, 1560, 1441, 1413, 1383, 1304, 1227, 1171, 1117, 1060, 1015, 865, 752, 611, $558 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR (500 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}\right): \delta 7.87-7.81(\mathrm{~m}, 1 \mathrm{H}), 7.37-7.31(\mathrm{~m}, 1 \mathrm{H}), 6.92-$ $6.86(\mathrm{~m}, 2 \mathrm{H}), 6.54(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.13-5.94(\mathrm{~m}, 2 \mathrm{H}), 5.44-$ $5.27(\mathrm{~m}, 1 \mathrm{H}), 4.78(\mathrm{brs}, 1 \mathrm{H}), 4.31-4.21(\mathrm{~m}, 4 \mathrm{H}), 2.49-2.27(\mathrm{~m}$, 4H), 1.69-1.44 (m, 8H), 1.32-1.27 (m, 6H). ${ }^{13}$ C NMR (125 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.9,154.9,147.3,141.2,139.8,135.9$, $134.0,129.0,128.5,128.2,121.8,82.0,65.8,62.6,61.7,55.1$, 32.7, 29.9, 29.1, 28.3, 27.9, 27.6, 14.5. HRMS (ESI): calcd for $\mathrm{C}_{24} \mathrm{H}_{31} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 593.09469; found: 593.09418.

## Diethyl 1-(-2-cyclohexylidene-5-(4-fluoro-2-iodophenylthio)

 cyclopent-3-enyl) hydrazine-1,2 dicarboxylate (7h)Yield: $47 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.43$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3725,3292,2927,2857,2315$, $1709,1578,1453,1412,1383,1303,1252,1168,1113,1061$, $863,768,722,666,614,560 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR $(500 \mathrm{MHz}$, $\left.\mathrm{CDCl}_{3}\right): \delta 7.64-7.47(\mathrm{~m}, 2 \mathrm{H}), 7.06-7.04(\mathrm{~m}, 1 \mathrm{H}), 6.54(\mathrm{~d}, J=6$ $\mathrm{Hz}, 1 \mathrm{H}), 6.33-6.21(\mathrm{~m}, 1 \mathrm{H}), 5.91-5.89(\mathrm{~m}, 1 \mathrm{H}), 5.45-5.26(\mathrm{~m}$, $1 \mathrm{H}), 4.77$ (brs, 1 H$), 4.23-4.11(\mathrm{~m}, 4 \mathrm{H}), 2.32-2.15(\mathrm{~m}, 4 \mathrm{H})$, 1.55-1.27 (m, 12H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.8$,
$155.2,140.0,135.9,129.0,128.2,126.9,126.8$, 125.3, 81.0, $65.0,62.4,61.7,54.8,34.7,31.9,31.6,26.9,26.4,22.8,14.7$, 14.5. HRMS (ESI): calcd for $\mathrm{C}_{23} \mathrm{H}_{28} \mathrm{FIN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 597.06962; found: 597.06993.

## Compound 7i

Yield: $39 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.5$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3730,3327,2917,2854,2391$, 2304, 1729, 1651, 1583, 1511, 1457, 1381, 1312, 1257, 1168, 1114, 1056, 724, 667, 613, $558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( 500 MHz , $\left.\mathrm{CDCl}_{3}\right): \delta 7.61-7.56(\mathrm{~m}, 2 \mathrm{H}), 7.07-7.04(\mathrm{~m}, 1 \mathrm{H}), 6.53(\mathrm{~d}, J=6$ $\mathrm{Hz}, 1 \mathrm{H}), 6.11(\mathrm{~s}, 1 \mathrm{H}), 5.90(\mathrm{~d}, J=2.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.45-5.26(\mathrm{~m}$, $1 \mathrm{H}), 4.69$ (brs, 1 H ), $4.20-4.01(\mathrm{~m}, 4 \mathrm{H}), 2.90(\mathrm{~s}, 1 \mathrm{H}), 2.57(\mathrm{~s}$, $1 \mathrm{H}), 1.97-1.84(\mathrm{~m}, 12 \mathrm{H}), 1.29-1.22(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR (125 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 156.8,154.7,147.6,135.8,132.9,130.6$, $130.1,129.1,128.5,128.2,126.5,125.4,81.7,64.4,62.8,62.2$, $57.0,39.7,39.3,38.8,36.9,36.8,35.8,35.1,34.7,28.1,27.8$, 14.6. HRMS (ESI): calcd for $\mathrm{C}_{27} \mathrm{H}_{32} \mathrm{FIN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 649.10092; found: 649.10101.

Diethyl 1-(-2-cyclohexylidene-5-(2-iodo-4-(trifluoromethyl) phenylthio) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (7j)
Yield: $50 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.43$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3728,3290,2928,2859,2358$, $2325,1711,1595,1512,1415,1382,1319,1258,1169,1126$, 1065, 723, 667, 612, $558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $8.04(\mathrm{~s}, 1 \mathrm{H}), 7.57(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 7.17-7.15(\mathrm{~m}, 1 \mathrm{H}), 6.37$ $(\mathrm{s}, 1 \mathrm{H}), 6.17-5.57(\mathrm{~m}, 3 \mathrm{H}), 4.23-4.19(\mathrm{~m}, 5 \mathrm{H}), 2.24-2.06(\mathrm{~m}$, 4H), 1.66-1.59 (m, 6H), 1.28-1.27 (m, 6H). ${ }^{13}$ C NMR (125 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}\right): \delta 155.4,153.5,141.7,136.2,132.0,131.4$, $129.1,128.5,128.2,125.4,122.4,121.7,82.9,63.4,62.7,62.3$, 55.1, 26.9, 26.0, 25.1, 22.9, 22.4, 19.8, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{24} \mathrm{H}_{28} \mathrm{~F}_{3} \mathrm{IN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ (M+Na): 647.06643; found: 647.06598.

Diethyl 1-(-2-(4-bromo-2-iodophenylthio)-5-cyclohexylidene cyclopent-3-enyl) hydrazine-1, 2 dicarboxylate ( 7 k )
Yield: $53 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.48$ (hexane/ethyl acetate, 7:3). IR (neat) $v_{\max }: 3724,3296,2927,2855,2392$, $1715,1605,1549,1443,1380,1315,1221,1167,1114,1057$, $763,668,613,558 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.94$ (brs, 1 H ), 7.48-7.45 (m, 2H), $6.57(\mathrm{~d}, J=6 \mathrm{~Hz}, 1 \mathrm{H}), 6.13$ (brs, $1 \mathrm{H}), 5.91(\mathrm{~s}, 1 \mathrm{H}), 5.42-5.22(\mathrm{~m}, 1 \mathrm{H}), 4.78(\mathrm{~m}, 1 \mathrm{H}), 4.34-4.17$ $(\mathrm{m}, 4 \mathrm{H}), 2.29-2.27(\mathrm{~m}, 2 \mathrm{H}), 2.12-2.05(\mathrm{~m}, 2 \mathrm{H}), 1.59-1.52(\mathrm{~m}$, $6 \mathrm{H}), 1.30-1.27(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.2$, $154.3,142.6,141.1,132.1,130.5,129.0,127.5,126.0,125.3$, $120.0,81.1,63.6,62.7,62.5,55.1,32.1,32.0,28.3,27.9,26.4$, 14.5, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{23} \mathrm{H}_{28} \mathrm{BrIN}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 656.98955; found: 656.98834.

General procedure for the Lewis acid catalyzed reaction of pentafulvene derived bicyclic hydrazines with alcohols

A mixture of pentafulvene derived diazabicyclic olefin (3.0 eqiuv.), alcohol ( 1.0 equiv.) and $\mathrm{Cu}(\mathrm{OTf})_{2}(5 \mathrm{~mol} \%)$ were weighed in a Schlenk tube and degassed for 10 minutes. Dry Toluene ( 2 ml ) was added and the reaction mixture was purged
with argon and allowed to stir at room temperature for 1 hour. The solvent was evaporated in vacuo and the residue on silica gel (100-200 mesh) column chromatography yielded trans-3,4disubstituted alkylidenecyclopentene.

## Diethyl-1-(2-cyclohexylidene-5-methoxycyclopent-3-enyl) hydrazine-1,2-dicarboxylate (9a)

Yield: $29 \%$ as pale yellow liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.55 (hexane/ethyl acetate $=7: 3$ ). IR (neat) $v_{\text {max }}: 3297,2927,2852,1715,1416,1383$, 1227, 1061, $760 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 6.61(\mathrm{~s}$, $1 \mathrm{H}), 6.35-6.21(\mathrm{~m}, 1 \mathrm{H}), 5.93(\mathrm{~s}, 1 \mathrm{H}), 5.13-4.98(\mathrm{~m}, 1 \mathrm{H}), 4.63-$ $4.52(\mathrm{~m}, 1 \mathrm{H}), 4.29-4.10(\mathrm{~m}, 4 \mathrm{H}), 3.47(\mathrm{~s}, 3 \mathrm{H}), 2.39-2.36(\mathrm{~m}$, $1 \mathrm{H}), 2.16-2.07(\mathrm{~m}, 3 \mathrm{H}), 1.59-1.54(\mathrm{~m}, 6 \mathrm{H}), 1.26-1.25(\mathrm{~m}, 6 \mathrm{H})$. ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 156.7,154.6,137.8,135.0$, $134.3,131.5,88.5,62.5,62.3,61.8,56.8,31.5,31.1,27.9,26.4$, 24.6, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{18} \mathrm{H}_{29} \mathrm{~N}_{2} \mathrm{O}_{5}(\mathrm{M}+1)$ : 353.20765; Found: 353.20721.

## Diisopropyl-1-(2-cyclohexylidene-5-methoxycyclopent-3enyl) hydrazine-1,2-dicarboxylate (9b)

Yield: $31 \%$ as a colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.60 (hexane: ethyl acetate $=7: 3$ ). IR (neat) $v_{\max }: 3441,3301,2935,1719$, 1468, 1376, 1297, $1238 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $6.60(\mathrm{~d}, 1 \mathrm{H}, J=5.5 \mathrm{~Hz}), 6.07-6.00(\mathrm{~m}, 1 \mathrm{H}), 5.92(\mathrm{~s}, 1 \mathrm{H}), 5.13-4.89$ $(\mathrm{m}, 3 \mathrm{H}), 4.63-4.55(\mathrm{~m}, 1 \mathrm{H}), 3.49(\mathrm{~s}, 3 \mathrm{H}), 2.35-2.26(\mathrm{~m}, 2 \mathrm{H})$, 2.13-2.08 (m, 2H), 1.58-1.54 (m, 6H), 1.26-1.22(m, 12H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.8,154.5,137.8,134.1,132.0$, $129.9,88.5,70.1,69.5,61.7,57.0,31.6,31.0,28.1,27.9,26.4$, 22.1, 21.8. HRMS (ESI): calcd for $\mathrm{C}_{20} \mathrm{H}_{32} \mathrm{~N}_{2} \mathrm{O}_{5}(\mathrm{M}+\mathrm{Na})$ : 403.22089; Found: 403.22098.

## Diisopropyl-1-(2-cyclohexylidene-5-ethoxycyclopent-3-enyl) hydrazine-1, 2-dicarboxylate (9c)

Yield: $31 \%$ as a pale yellow viscous liquid, $\mathrm{R}_{\mathrm{f}}: 0.66$ (hexane : ethyl acetate=7:3). IR (neat) $v_{\text {max }}: 3303,2935,1715,1411$, 1232, 1101, $1061 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 6.59$ $(\mathrm{d}, 1 \mathrm{H}, J=5 \mathrm{~Hz}), 6.06-5.98(\mathrm{~m}, 1 \mathrm{H}), 5.92(\mathrm{~s}, 1 \mathrm{H}), 5.12-4.89(\mathrm{~m}$, $3 \mathrm{H}), 4.74-4.63(\mathrm{~m}, 1 \mathrm{H}), 3.88-3.80(\mathrm{~m}, 1 \mathrm{H}), 3.60($ brs, 1 H$)$, 2.35-2.26 (m, 2H), 2.12-2.04 (m, 2H), 1.76-1.58 (m, 6H), 1.25$1.22(\mathrm{~m}, 15 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.6,154.6$, $137.4,133.9,132.8,132.1,86.8,69.9,69.5,64.8,62.1,34.7$, $31.6,31.0,28.1,26.9,26.6,25.2,22.2,22.0,15.5$. HRMS (ESI) calcd for $\mathrm{C}_{21} \mathrm{H}_{34} \mathrm{~N}_{2} \mathrm{O}_{5} \quad\left(\mathrm{M}^{+}\right):$395.24677; Found: 395.14380.

## Diethyl-1-(-2-cyclohexylidene-5-(3-phenylprop-2-ynyloxy) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (9d)

Yield: $27 \%$ as a colourless liquid $\mathrm{R}_{\mathrm{f}}$ : 0.55 (hexane: ethyl acetate $=7: 3$ ). IR (neat) $v_{\text {max }}: 3316,3059,2935,2861,2223,1712$, 1603, 1413, 1380, 1232, 1173, $1062 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( 500 MHz , $\left.\mathrm{CDCl}_{3}\right): \delta 7.44-7.28(\mathrm{~m}, 5 \mathrm{H}), 6.63(\mathrm{~d}, 1 \mathrm{H}, J=4.5 \mathrm{~Hz}), 6.28-6.16$ $(\mathrm{m}, 1 \mathrm{H}), 5.99(\mathrm{~d}, 1 \mathrm{H}, J=3.5 \mathrm{~Hz}), 5.15-5.12(\mathrm{~m}, 1 \mathrm{H}), 5.08-$ $5.05(\mathrm{~m}, 1 \mathrm{H}), 4.66-4.49(\mathrm{~m}, 2 \mathrm{H}), 4.23-4.06(\mathrm{~m}, 4 \mathrm{H}), 2.40-2.35$ $(\mathrm{m}, 1 \mathrm{H}), 2.24-2.03(\mathrm{~m}, 3 \mathrm{H}), 1.61-1.54(\mathrm{~m}, 6 \mathrm{H}), 1.25-1.23(\mathrm{~m}$, $6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.9,155.1,134.7,131.8$, $131.2,129.0,128.1,122.9,99.1,87.0,85.7,62.5,61.8,57.5$,
31.6, 31.2, 30.8, 28.0, 26.4, 14.6, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{26} \mathrm{H}_{32} \mathrm{~N}_{2} \mathrm{NaO}_{5}$ (M+Na): 475.22089; Found: 475.22125.

## Diethyl-1-(-2-cyclohexylidene-5-(prop-2-ynyloxy) cyclopent-3-enyl) hydrazine-1,2-dicarboxylate (9e)

Yield: $21 \%$ as a colourless liquid $\mathrm{R}_{\mathrm{f}}$ : 0.53 (Hexane: Ethyl acetate $=7: 3$ ). IR (neat) $v_{\max }: 3292,2922,2854,1714,1414$, 1232, $1061 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 6.62(\mathrm{~d}, 1 \mathrm{H}$, $J=4.5 \mathrm{~Hz}), 6.07(\mathrm{brs}, 1 \mathrm{H}), 5.95(\mathrm{~s}, 1 \mathrm{H}), 5.08(\mathrm{brs}, 1 \mathrm{H}), 4.88(\mathrm{~s}$, $1 \mathrm{H}), 4.42-4.10(\mathrm{~m}, 6 \mathrm{H}), 2.40-2.35(\mathrm{~m}, 2 \mathrm{H}), 2.24-2.06(\mathrm{~m}, 3 \mathrm{H})$, 1.66-1.55 (m,6H), 1.28-1.24(m, 6H). ${ }^{13}$ C NMR ( 125 MHz , $\left.\mathrm{CDCl}_{3}\right): \delta 155.1,154.4,136.8,134.3,132.0,129.4,87.8,74.5$, $65.2,62.5,57.3,31.7,31.3,29.7,26.8,25.7,20.8,14.6,14.1$. HRMS (ESI) calcd for $\mathrm{C}_{20} \mathrm{H}_{28} \mathrm{~N}_{2} \mathrm{NaO}_{5}(\mathrm{M}+\mathrm{Na})$ : 399.18959; Found: 399.19028.

## Dibenzyl-1-(2-cyclohexylidene-5-ethoxycyclopent-3-enyl) hydrazine-1,2-dicarboxylate (9f)

Yield: $40 \%$ as a pale yellow liquid liquid ; $\mathrm{R}_{\mathrm{f}}$ : 0.64 (hexane : ethyl acetate $=7: 3$ ). IR (neat) $v_{\max }: 3287,3033,2933,2860$, 1718, 1498, 1454, 1408, 1220, 1127, $1084 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.30-7.24(\mathrm{~m}, 10 \mathrm{H}), 6.55(\mathrm{~s}, 1 \mathrm{H}), 6.29-$ $6.21(\mathrm{~m}, 1 \mathrm{H}), 5.90(\mathrm{~s}, 1 \mathrm{H}), 5.26-4.72(\mathrm{~m}, 7 \mathrm{H}), 3.59-3.48(\mathrm{~m}, 1 \mathrm{H})$, 2.32-2.18 (m, 1H), 2.11-1.96 (m, 3H), 1.70-1.40 (m, 6H), 1.25$1.10(\mathrm{~m}, 3 \mathrm{H}) .{ }^{13} \mathbf{C} \mathbf{N M R}\left(125 \mathrm{MHz}, \mathrm{CDCl}_{3}\right): \delta 155.8,154.7$, $135.1,134.0,132.7,131.5,128.5,128.1,127.9,127.8,127.6$, 87.2, 68.1, 67.6, 65.0, 62.5, 31.5, 31.1, 27.9, 26.4, 25.6, 15.3. HRMS (EI): calcd for $\mathrm{C}_{29} \mathrm{H}_{34} \mathrm{~N}_{2} \mathrm{O}_{5} \mathrm{Na},(\mathrm{M}+\mathrm{Na}): 513.23654$; Found: 513.23627.

## Diethyl-1-(-2-(2-bromoethoxy)-5-cyclohexylidenecyclopent-3enyl) hydrazine-1, 2-dicarboxylate (9g)

Yield: $26 \%$ as a colourless liquid $\mathrm{R}_{\mathrm{f}}$ : 0.63 (hexane: ethyl acetate $=7: 3$ ). IR (neat) $v_{\max }: 3320,2931,1711,1414,1379,1234$, $1061 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}\right): \delta 6.61(\mathrm{~d}, 1 \mathrm{H}$, $J=5.5 \mathrm{~Hz}), 6.15-6.07(\mathrm{~m}, 1 \mathrm{H}), 5.93(\mathrm{~s}, 1 \mathrm{H}), 5.12-5.01(\mathrm{~m}, 1 \mathrm{H})$, 4.80-4.69 (m, 1H), 4.31-4.00 (m,5H), 3.90-3.83 (m, 1H), 3.49 (brs, 2 H$), 2.39-2.36(\mathrm{~m}, 1 \mathrm{H}), 2.26-2.05(\mathrm{~m}, 3 \mathrm{H}), 1.67-1.50$ $(\mathrm{m}, 6 \mathrm{H}), 1.39-1.22(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR $\left(125 \mathrm{MHz}, \mathrm{CDCl}_{3}\right): \delta$ 156.3, 155.1, 138.3, 134.5, 131.7, 128.3, 87.5, 69.9, 69.3, 62.7, 62.0, 32.0, 31.6, 29.7.28.1, 27.9, 26.4, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{19} \mathrm{H}_{29} \mathrm{BrN}_{2} \mathrm{O}_{5}, \quad(\mathrm{M}+\mathrm{Na}): 467.11575$; Found: 467.11561.

Diethyl 1-((1S, 2S)-2-(benzyloxy)-5-cyclohexylidenecyclopent-3enyl) hydrazine-1,2-dicarboxylate (9h)

Yield: $72 \%$ as a pale yellow liquid), $\mathrm{R}_{\mathrm{f}}$ : 0.64 (hexane: ethyl acetate $=7: 3$ ). IR (neat) $v_{\text {max }}: 3296,2923,2855,1711,1414$, 1376, 1267, 1225, $1063 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $7.36-7.24(\mathrm{~m}, 5 \mathrm{H}), 6.60(\mathrm{~d}, 1 \mathrm{H}, J=5 \mathrm{~Hz}), 6.05-5.94(\mathrm{~m}, 1 \mathrm{H})$, $5.84(\mathrm{~s}, 1 \mathrm{H}), 5.24-5.10(\mathrm{~m}, 1 \mathrm{H}), 4.85-4.70(\mathrm{~m}, 2 \mathrm{H}), 4.62-4.60$ $(\mathrm{m}, 1 \mathrm{H}), 4.24-4.10(\mathrm{~m}, 4 \mathrm{H}), 2.39-2.36(\mathrm{~m}, 1 \mathrm{H}), 2.26-2.05$ $(\mathrm{m}, 3 \mathrm{H}), 1.59-1.53(\mathrm{~m}, 6 \mathrm{H}), 1.28-1.24(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR (125 $\mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 156.7,155.1,138.6,134.3,132.5,130.9$, $129.9,128.5,128.2,127.4,126.9,88.1,71.8,62.5,62.0,53.3$,
31.6, 30.6, 28.0, 27.8, 26.4, 14.6, 14.4. HRMS (ESI): calcd for $\mathrm{C}_{24} \mathrm{H}_{32} \mathrm{~N}_{2} \mathrm{O}_{5}(\mathrm{M}+\mathrm{Na}): 451.22089$; Found: 451.22040

## Diethyl-1-(-2-cyclohexylidene-5-(2-iodobenzyloxy) cyclopent-3enyl) hydrazine-1, 2-dicarboxylate (9i)

Yield: $55 \%$ as a pale yellow liquid), $\mathrm{R}_{\mathrm{f}}$ : 0.61 (hexane: ethyl acetate $=7: 3$ ). IR (neat) $v_{\text {max }}: 3296,2923,2855,1711,1414$, 1376, 1267, 1225, $1063 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta$ $7.81(\mathrm{~d}, 1 \mathrm{H}, J=7.5 \mathrm{~Hz}), 7.48(\mathrm{~d}, 1 \mathrm{H}, \mathrm{J}=7 \mathrm{~Hz}), 7.34(\mathrm{dd}, 1 \mathrm{H}$, $\left.J_{l}=14 \mathrm{~Hz}, J_{2}=5 \mathrm{~Hz}\right), 6.96(\mathrm{brs}, 1 \mathrm{H}), 6.66(\mathrm{~d}, 1 \mathrm{H}, J=5.5 \mathrm{~Hz}), 6.10$ (brs, 1 H$), 6.02-5.94(\mathrm{~m}, 1 \mathrm{H}), 5.32-5.17(\mathrm{~m}, 1 \mathrm{H}), 4.93-4.80(\mathrm{~m}$, $2 \mathrm{H}), 4.61-4.58(\mathrm{~m}, 1 \mathrm{H}), 4.37-4.12(\mathrm{~m}, 4 \mathrm{H}), 2.42-2.39(\mathrm{~m}, 1 \mathrm{H})$, 2.28-2.10 (m, 3H), 1.64-1.58 (m, 6H), 1.30-1.25 (m, 6H). ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 156.0,155.0,140.9,139.0,137.9$, 134.7, 131.7, 129.0, 128.1, 87.6, 75.0, 62.8, 62.6, 61.9, 31.6, 31.2, 28.1, 27.9, 26.4, 14.5. HRMS (ESI): calcd for $\mathrm{C}_{24} \mathrm{H}_{31} \mathrm{IN}_{2} \mathrm{O}_{5}(\mathrm{M}+\mathrm{Na})$ : 577.11753 ; Found: 577.11853.

## Diethyl-1-(2-cyclohexylidene-5-ethoxycyclopent-3-enyl) hydrazine-1,2-dicarboxylate (9j)

Yield: $24 \%$ as a pale yellow liquid $\mathrm{R}, \mathrm{f}$ : 0.51 (hexane : ethyl acetate $=7: 3$ ). IR (neat) $v_{\text {max }}: 2923,2855,2355,1711,1411$, 1232, 1101, $1061 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 6.60(\mathrm{~d}$, $1 \mathrm{H}, J=5 \mathrm{~Hz}), 6.06(\mathrm{brs}, 1 \mathrm{H}), 5.93-5.89(\mathrm{~m}, 1 \mathrm{H})$ ), 5.13-4.98 (m, $1 \mathrm{H}), 4.72-4.61(\mathrm{~m}, 1 \mathrm{H}), 4.29-4.10(\mathrm{~m}, 4 \mathrm{H}), 3.87-3.78(\mathrm{~m}, 1 \mathrm{H})$, 3.59- $3.54(\mathrm{~m}, 1 \mathrm{H}), 2.38-2.35(\mathrm{~m}, 1 \mathrm{H})$, 2.25-2.05 (m, 3H), $1.63-1.53(\mathrm{~m}, 6 \mathrm{H}), 1.27-1.22(\mathrm{~m}, 9 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR $(125 \mathrm{MHz}$, $\left.\mathrm{CDCl}_{3}\right): \delta 156.5,155.5,134.5,133.0,131.7,130.5,87.2,70.1$, $65.2,62.9,62.6,32.0,31.5,30.1,28.2,26.8,26.0,15.8,14.8$.
HRMS (ESI): calcd for $\mathrm{C}_{19} \mathrm{H}_{30} \mathrm{~N}_{2} \mathrm{O}_{5},(\mathrm{M}+\mathrm{Na}): 389.20524$, Found: 389.20565.

## General procedure for the intramolecular Heck reaction

A mixture of trans-3,4-disubstituted alkylidenecyclopentene. (1.0 equiv), $\mathrm{Pd}(\mathrm{OAc})_{2}(5 \mathrm{~mol} \%), \mathrm{PPh}_{3}(10 \mathrm{~mol} \%)$ and $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ (1.5 equiv) were weighed in a schlenk tube and degassed for 10 minutes. Dry acetonitrile ( 2 ml ) was added and the reaction mixture was purged with argon and allowed to stir at $80{ }^{\circ} \mathrm{C}$ for 12 hours. The solvent was evaporated in vacuo and the residue on silica gel (100-200 mesh) column chromatography yielded indoline-pyrazolidine fused cyclopentene.

General procedure for the one-pot synthesis of indolinepyrazolidine fused cyclopentene
A mixture of pentafulvene derived diazabicyclic olefin (3.0 eqiuv), $o$-iodoaniline ( 1.0 equiv), $[\mathrm{Pd}(\text { allyl }) \mathrm{Cl}]_{2}(5 \mathrm{~mol} \%), \mathrm{PPh}_{3}$ ( $10 \mathrm{~mol} \%$ ), $\mathrm{Sc}(\mathrm{OTf})_{3}(2 \mathrm{~mol} \%)$ and $\mathrm{Cs}_{2} \mathrm{CO}_{3}$ ( 1.5 equiv) were weighed in a schlenk tube and degassed for 10 minutes. Dry acetonitrile $(2 \mathrm{ml})$ and toluene $(0.5 \mathrm{ml})$ were added and the reaction mixture was purged with argon and allowed to stir at $80^{\circ} \mathrm{C}$ for 12 hours. The solvent was evaporated in vacuo and the residue on silica gel (100-200 mesh) column chromatography yielded indoline-pyrazolidine fused cyclopentene.

Yield: $54 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.31$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3388,3263,2969,2919,2848$, 1708, 1605, 1558, 1490, 1410, 1389, 1313, 1289, 1218, 1120, $1071,938,731 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.07-$ $7.00(\mathrm{~m}, 2 \mathrm{H}), 6.74-6.67(\mathrm{~m}, 2 \mathrm{H}), 5.91(\mathrm{t}, J=3 \mathrm{~Hz}, 1 \mathrm{H}), 4.69(\mathrm{~s}$, $1 \mathrm{H}), 4.55(\mathrm{~s}, 1 \mathrm{H}), 4.54(\mathrm{brs}, 1 \mathrm{H}), 4.27-4.11(\mathrm{~m}, 5 \mathrm{H}), 1.71(\mathrm{~s}$, 3H), 1.32-1.24 (m, 9H). ${ }^{13}$ C NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ $155.6,154.8,148.9,139.8,127.5,126.9,125.9,123.2,118.0$, 109.2, 64.4, 61.4, 61.0, 56.1, 21.4, 20.9, 14.5, 14.1. MS (ESI): Calcd for $\mathrm{C}_{20} \mathrm{H}_{25} \mathrm{~N}_{3} \mathrm{O}_{4}, \mathrm{M}^{+}$: 371.18451; Found, (M+1): 372.19001 .

## Compound 10b

Yield: $74 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.54$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3390,3288,3060,3038,297$, 2849, 1717, 1594, 1498, 1454, 1404, 1318, 1279, 1218, 1131, 1056, 1011, 916, $748,670 \mathrm{~cm}^{-1} . \mathbf{1}^{\mathbf{H}}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta \quad 7.34-7.25(\mathrm{~m}, 12 \mathrm{H}), 7.02-6.97(\mathrm{~m}, 2 \mathrm{H}), 6.69(\mathrm{t}, J=7$ $\mathrm{Hz}, 1 \mathrm{H}), 5.85(\mathrm{~s}, 1 \mathrm{H}), 5.17-5.09(\mathrm{~m}, 4 \mathrm{H}), 4.69$ (brs, 1H), 4.49 (brs, 1 H ), $4.40(\mathrm{brs}, 1 \mathrm{H}), 1.79-1.552(\mathrm{~m}, 3 \mathrm{H}), 1.25-1.20(\mathrm{~m}$, 3H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ 157.7, 156.1, $149.8,136.0,128.6,128.5,128.1,127.9,127.7,127.3,126.9$, 124.3, 119.0, 70.1, 68.2, 57.2, 39.4, 23.3, 23.2. MS (ESI): Calcd for $\mathrm{C}_{30} \mathrm{H}_{29} \mathrm{~N}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 518.20558; Found: 518.20322 $\left(\mathrm{C}_{30} \mathrm{H}_{29} \mathrm{~N}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Compound 10c

Yield: $65 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.31$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3377,3058,2918,2851,1729$, $1604,1461,1403,1118,1050,740,699 \mathrm{~cm}^{-1} .{ }^{\mathbf{1}} \mathbf{H}$ NMR (500 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.36-7.31(\mathrm{~m}, 12 \mathrm{H}), 7.00(\mathrm{t}, J=12.5$ $\mathrm{Hz}, 1 \mathrm{H}), 6.69(\mathrm{t}, J=12 \mathrm{~Hz}, 1 \mathrm{H}), 5.89(\mathrm{~s}, 1 \mathrm{H}), 5.20-5.12(\mathrm{~m}$, 4 H ), 4.69 (s, 2H), 4.46 (brs, 1H), 4.35 (brs, 1H), 2.71 (brs, 1H), 2.48 (brs, 1 H ), $1.97-1.54(\mathrm{~m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C} \mathbf{N M R}(125 \mathrm{MHz}$, $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): ~ \delta 154.9,152.1,149.8,136.0,128.6,128.5$, $128.1,127.9,127.7,127.3,126.9,124.3,119.0,76.1,67.8$, 65.2, 56.9, 46.2, 31.9, 29.3, 27.4, 23.9. MS (ESI): Calcd for $\mathrm{C}_{32} \mathrm{H}_{31} \mathrm{~N}_{3} \mathrm{O}_{4}, \quad \mathrm{M}^{+}: \quad 521.23146$; Found (M+1): 522.23688 $\left(\mathrm{C}_{32} \mathrm{H}_{32} \mathrm{~N}_{3} \mathrm{O}_{4}\right)$.

## Compound 10d

Yield: $72 \%$ as pale yellow solid $\mathrm{Mp}=136-139{ }^{\circ} \mathrm{C} ; \mathrm{R}_{\mathrm{f}}: 0.31$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3368,3268,2990$, 2931, 2860, 1718, 1588, 1410, 1282, 1228, 1124, 1056, 1016, $746,694 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.05$ (m, 2 H ), 6.73-6.66 (m, 2H), $6.11(\mathrm{~s}, 1 \mathrm{H}), 4.64$ (brs, 1 H ), 4.48 (brs, $1 \mathrm{H}), 4.37-4.35(\mathrm{~m}, 1 \mathrm{H}), 4.23-4.12(\mathrm{~m}, 5 \mathrm{H}), 2.80(\mathrm{~s}, 1 \mathrm{H}), 2.55-$ $2.51(\mathrm{~m}, 1 \mathrm{H}), 2.21-2.12(\mathrm{~m}, 2 \mathrm{H}), 1.90-1.54(\mathrm{~m}, 6 \mathrm{H}), 1.59-1.54$ (m, 4H), 1.29-1.22 (m, 6H). ${ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 157.9,157.1,154.5,149.5,127.9,124.2,123.8,119.3$, $119.0,110.2,109.9,71.4,62.1,57.0,37.2,35.7,35.4,34.6$, 32.5, 32.2, 32.0, 27.1, 27.0, 14.7, 14.5. MS (ESI): Calcd for $\mathrm{C}_{27} \mathrm{H}_{33} \mathrm{~N}_{3} \mathrm{O}_{4}, \quad \mathrm{M}^{+}: ~ 463.24711$; Found, (M+1): 464.25262 $\left(\mathrm{C}_{27} \mathrm{H}_{34} \mathrm{~N}_{3} \mathrm{O}_{4}\right)$.

## Compound 10a

## Compound 10e

Yield: $69 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.36 (hexane/ethyl acetate $=3: 1$ ). $\mathbf{I R}$ (Neat) $v_{\max }: 3380,3051,2978,2920,2856$, $2666,1704,1683,1606,1460,1277,1106,956,912,746 \mathrm{~cm}^{-1}$. ${ }^{1} \mathbf{H}$ NMR $\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.06-7.02(\mathrm{~m}, 2 \mathrm{H}), 6.72-$ $6.65(\mathrm{~m}, 2 \mathrm{H}), 6.10(\mathrm{~d}, J=5.5 \mathrm{~Hz}, 1 \mathrm{H}), 5.02-4.87(\mathrm{~m}, 2 \mathrm{H}), 4.62-$ $4.06(\mathrm{~m}, 4 \mathrm{H}), 2.83(\mathrm{brs}, 1 \mathrm{H}), 2.61-2.51(\mathrm{~m}, 1 \mathrm{H}), 2.35-2.11(\mathrm{~m}$, $2 \mathrm{H}), 1.89-1.37(\mathrm{~m}, 10 \mathrm{H}), 1.25-1.21(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR (125 $\left.\mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 157.4,156.8,149.8,129.0,128.2,127.9$, $125.3,124.2,118.9,110.1,75.6,71.4,69.5,56.9,37.2,35.8$, 35.4, 34.6, 32.6, 32.3, 32.0, 27.2, 22.2, 22.1. MS (ESI): Calcd for $\mathrm{C}_{29} \mathrm{H}_{37} \mathrm{~N}_{3} \mathrm{O}_{4},\left(\mathrm{M}^{+}\right): 491.27841$; Found (M+1): 492.28394 $\left(\mathrm{C}_{29} \mathrm{H}_{38} \mathrm{~N}_{3} \mathrm{O}_{4}\right)$.

## Compound $10 f$

Yield: $46 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.37$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3381,980,2938,2861,1738$, 1712, 1594, 1499, 1451, 1410, 1284, 1230, 1126, 1062, 1007, $746,698 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 8.03$ (d, $J$ $=14.5 \mathrm{~Hz}, 1 \mathrm{H}), \quad 7.95(\mathrm{~s}, 1 \mathrm{H}), 6.57(\mathrm{~d}, J=14.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.09$ $(\mathrm{s}, 1 \mathrm{H}), 5.33(\mathrm{~s}, 1 \mathrm{H}), 4.62-4.56(\mathrm{~m}, 2 \mathrm{H}), 4.23-4.12(\mathrm{~m}, 5 \mathrm{H})$, $2.76(\mathrm{~s}, 1 \mathrm{H}), 2.50-2.03(\mathrm{~m}, 4 \mathrm{H}), 1.91-1.42(\mathrm{~m}, 9 \mathrm{H}), 1.29-1.24$ $(\mathrm{m}, 6 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $\left.125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 155.9,154.3$, $147.2,138.8,133.4,131.9,129.5,128.5,118.9,112.9,75.6$, $64.3,63.3,62.4,56.1,40.1,39.5,38.9,38.8,36.8,35.0,34.5$, 28.1, 27.9, 14.6, 14.4. MS (ESI): Calcd for $\mathrm{C}_{27} \mathrm{H}_{32} \mathrm{~N}_{4} \mathrm{O}_{6}, \mathrm{M}^{+}$: 508.23218; Found (M+1): $509.23765\left(\mathrm{C}_{27} \mathrm{H}_{33} \mathrm{~N}_{4} \mathrm{O}_{6}\right)$.

## Compound 10g

Yield: $42 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.40$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3293,2922,2852,1716,1587$, 1499, 1456, 1381, 1316, 1282, 1178, 1109, 1038, $743 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $\left.500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 8.05(\mathrm{~d}, J=9 \mathrm{~Hz}, 1 \mathrm{H}), 7.95$ $(\mathrm{s}, 1 \mathrm{H}), 6.57(\mathrm{~d}, J=8.5 \mathrm{~Hz}, 1 \mathrm{H}), 6.10(\mathrm{~s}, 1 \mathrm{H}), 5.01-4.89(\mathrm{~m}$, $2 \mathrm{H}), 4.62(\mathrm{~s}, 1 \mathrm{H}), 4.57-4.52(\mathrm{~m}, 3 \mathrm{H}), 2.80(\mathrm{~s}, 1 \mathrm{H}), 2.53(\mathrm{~d}, J=$ $13.5 \mathrm{~Hz}, 1 \mathrm{H}), 2.21-2.11(\mathrm{~m}, 2 \mathrm{H}), 1.92-1.53(\mathrm{~m}, 10 \mathrm{H}), 1.31-1.24$ $(\mathrm{m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 155.6,155.1$, $153.3,148.9,138.1,126.2,124.7,121.2,119.3,105.7,69.8$, $68.2,68.1,54.5,35.4,34.0,33.6,32.5,30.9,30.7,30.3,27.7$, 25.4, 25.2, 20.5, 20.4. MS (ESI): Calcd for $\mathrm{C}_{29} \mathrm{H}_{36} \mathrm{~N}_{4} \mathrm{O}_{6},\left(\mathrm{M}^{+}\right)$: 536.26348; Found (M+1): $537.26905\left(\mathrm{C}_{29} \mathrm{H}_{37} \mathrm{~N}_{4} \mathrm{O}_{6}\right)$.

## Compound 10h

Yield: $72 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}$ : 0.34 (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3375,3051,2933,2861,1698$, 1605, 1459, 1407, 1377, 1334, 1287, 1171, 1131, 1098, 1032, 897, 870, $750 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ 7.71-7.04 (m, 2H), 6.74-6.68 (m, 2H), $6.06(\mathrm{~s}, 1 \mathrm{H}), 4.66(\mathrm{~s}$, $1 \mathrm{H}), 4.54(\mathrm{~d}, J=6.5 \mathrm{~Hz}, 1 \mathrm{H}), 4.37$ (brs, 1 H$), 4.23-4.13$ (m, $5 \mathrm{H}), 2.46(\mathrm{t}, J=10 \mathrm{~Hz}, 1 \mathrm{H}), 2.36(\mathrm{~s}, 1 \mathrm{H}), 1.97(\mathrm{~d}, J=10.5 \mathrm{~Hz}$, $2 \mathrm{H}), 1.63-1.20(\mathrm{~m}, 12 \mathrm{H}) .{ }^{13} \mathbf{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 155.6,154.9,148.8,139.9,128.4,127.5,126.1,125.9,123.3$, $122.7,118.0,109.2,64.3,61.3,56.0,32.1,30.4,28.7,24.5$, 22.9, 22.0, 13.6, 13.4. MS (ESI): Calcd for $\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{~N}_{3} \mathrm{O}_{4} \mathrm{Na}$ : 434.20558; Found: $434.20336\left(\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{~N}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Compound 10i

Yield: $63 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.43$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3377$, 3051, 2928, 2856, 2670, 1708, 1694, 1606, 1462, 1379, 1232, 1107, 1022, 916, 748 $\mathrm{cm}^{-1}$. ${ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta$ 7.08-7.03 ( m , $2 \mathrm{H}), 6.75-6.68(\mathrm{~m}, 2 \mathrm{H}), 6.03(\mathrm{~s}, 1 \mathrm{H}), 4.99-4.86(\mathrm{~m}, 2 \mathrm{H}), 6.46$ $(\mathrm{s}, 1 \mathrm{H}), 4.50(\mathrm{~s}, 1 \mathrm{H}), 4.36(\mathrm{~s}, 1 \mathrm{H}), 2.43(\mathrm{~m}, 1 \mathrm{H}), 2.17(\mathrm{brs}, 1 \mathrm{H})$, 1.99-1.91 (m, 2H), 1.60-1.25 (m, 18H). ${ }^{13}$ C NMR ( 125 MHz , $\left.\mathrm{CDCl}_{3}, \mathrm{TMS}\right): ~ \delta 156.1,154.7,145.9,138.7,133.6,132.8$, 129.6, 129.3, 118.8, 118.2, 110.2, 69.9, 63.2, 57.8, 32.0, 31.8, 28.2, 27.8, 26.4, 22.6, 22.1. MS (ESI): Calcd for $\mathrm{C}_{25} \mathrm{H}_{33} \mathrm{~N}_{3} \mathrm{O}_{4}$, $\mathrm{M}^{+}$: 439.24711 ; Found, $(\mathrm{M}+1)$ : $440.25259\left(\mathrm{C}_{25} \mathrm{H}_{34} \mathrm{~N}_{3} \mathrm{O}_{4}\right)$.

## Compound 10j

Yield: $40 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.34$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\text {max }}: 3376,2983,2924,2857,2359$, 1706, 1597, 1468, 1410, 1379, 1307, 1230, 1172, 1132, 1061, 939, $868 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H} \mathbf{N M R}\left(500 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}\right): \delta 7.07-7.02$ $(\mathrm{m}, 2 \mathrm{H}), 6.74-6.67(\mathrm{~m}, 2 \mathrm{H}), 5.95(\mathrm{t}, J=3 \mathrm{~Hz}, 1 \mathrm{H}), 4.64(\mathrm{~s}, 1 \mathrm{H})$, $4.52(\mathrm{~s}, 1 \mathrm{H}), 4.39-4.38(\mathrm{~m}, 1 \mathrm{H}), 4.22-4.17(\mathrm{~m}, 5 \mathrm{H}), 2.52-2.46$ (m, 2H), 2.19-2.16 (m, 2H), 1.59 (m, 8H), 1.29-1.26 (m, 6H).
${ }^{13}$ C NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 155.5,155.2,145.2$, $135.5,128.0,127.9,124.4,122.7,119.1,110.6,62.4,62.0$, 61.9, 56.8, 34.6, 32.3, 29.8, 29.1, 24.5, 14.5. MS (ESI): Calcd for $\mathrm{C}_{24} \mathrm{H}_{31} \mathrm{~N}_{3} \mathrm{NaO}_{4}$ : 448.22123; Found: 448.22079 $\left(\mathrm{C}_{23} \mathrm{H}_{29} \mathrm{~N}_{3} \mathrm{O}_{4} \mathrm{Na}\right)$.

## Compound 10k

Yield: $41 \%$ as colourless viscous liquid; $\mathrm{R}_{\mathrm{f}}: 0.45$ (hexane/ethyl acetate $=3: 1$ ). IR (Neat) $v_{\max }: 3376,3261,2971,2942,2858$, $1712,1600,1541,1501,1400,1395,1321,1282,1223,1110$, $1071,929,731 \mathrm{~cm}^{-1} . \mathbf{H}^{\mathbf{1}} \mathbf{~ N M R ~ ( ~} 300 \mathrm{MHz}, \mathrm{CDCl}_{3}, \mathrm{TMS}$ ): $\delta 7.32$ $(\mathrm{d}, J=8.1 \mathrm{~Hz}, 1 \mathrm{H}), 7.24(\mathrm{~s}, 1 \mathrm{H}), 6.68(\mathrm{~d}, J=8.1 \mathrm{~Hz}, 1 \mathrm{H})$, $5.91(\mathrm{~s}, 1 \mathrm{H}), 4.67-4.56(\mathrm{~m}, 4 \mathrm{H}), 4.26-4.14(\mathrm{~m}, 4 \mathrm{H}), 1.72(\mathrm{~s}, 3 \mathrm{H})$, 1.34-1.26 (m, 9H). ${ }^{13} \mathbf{C}$ NMR ( $75 \mathrm{MHz}, \mathrm{CDCl}_{3}$, TMS): $\delta 155.3$, $154.9,147.9,140.2,127.4,126.2,125.1,121.5,108.9,65.5$, 62.6, 62.0, 56.5, 24.7, 23.0, 14.7, 14.5. MS (ESI): Calcd for $\mathrm{C}_{21} \mathrm{H}_{24} \mathrm{~F}_{3} \mathrm{~N}_{3} \mathrm{O}_{4}, \mathrm{M}^{+}: 439.17189$; Found, (M+1): 440.17828.

## Compound 11a

Yield: $41 \%$ as yellow viscous liquid; $\mathrm{R}_{f}=0.43$ (hexane/ethyl acetate, $7: 3$ ). IR (neat) $v_{\text {max }}: 2929,2859,2312,1711,1591$, $1452,1404,1377,1323,1277,1211,1130,1032,899,792$, $746,662,612 \mathrm{~cm}^{-1} .{ }^{1} \mathbf{H}$ NMR ( $500 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 7.21-7.14$ $(\mathrm{m}, 2 \mathrm{H}), 7.07-7.02(\mathrm{~m}, 2 \mathrm{H}), 6.14-6.13(\mathrm{~m}, 1 \mathrm{H}), 4.93($ brs, 1 H$)$, $4.84(\mathrm{~d}, J=7 \mathrm{~Hz}, 1 \mathrm{H}), 4.24-4.13(\mathrm{~m}, 5 \mathrm{H}), 2.51-2.47(\mathrm{~m}, 2 \mathrm{H})$, 2.00-1.98 (m, 2H), 1.63-1.57 (m, 6H), 1.31-1.20 (m, 6H). ${ }^{13} \mathrm{C}$ NMR ( $125 \mathrm{MHz}, \mathrm{CDCl}_{3}$ ): $\delta 155.9,155.4,141.1,138.5,131.5$, $127.9,124.5,124.4,123.2,122.7,83.9,63.6,62.4,62.0,53.3$, 31.5, 29.7, 26.9, 25.6, 24.0, 23.1, 14.6, 14.5. HRMS (ESI): calcd for $\mathrm{C}_{23} \mathrm{H}_{28} \mathrm{~N}_{2} \mathrm{NaO}_{4} \mathrm{~S}$ [M+Na]: 451.16675; found: 451.16537.

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