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Article

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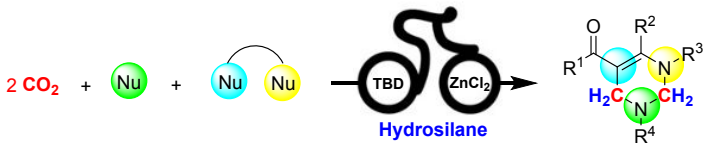
One-pot Methylenation-Cyclization Employing Two Molecules of CO_2 with Arylamines and Enaminones

Yulei Zhao*,† Xu Liu,† Lijun Zheng,† Yulan Du,† Xinrui Shi,† Yunlin Liu,‡ Zhengquan Yan*,† Jinmao You*,†,§ and Yuanye Jiang*,†

† School of Chemistry and Chemical Engineering, Qufu Normal University, Qufu, 273165, China.

‡ School of Chemistry and Chemical Engineering, Guangzhou University, Guangzhou, 510006, China.

§ Northwest Institute of Plateau Biology, Chinese Academy of Science, Xining, 810001, China.

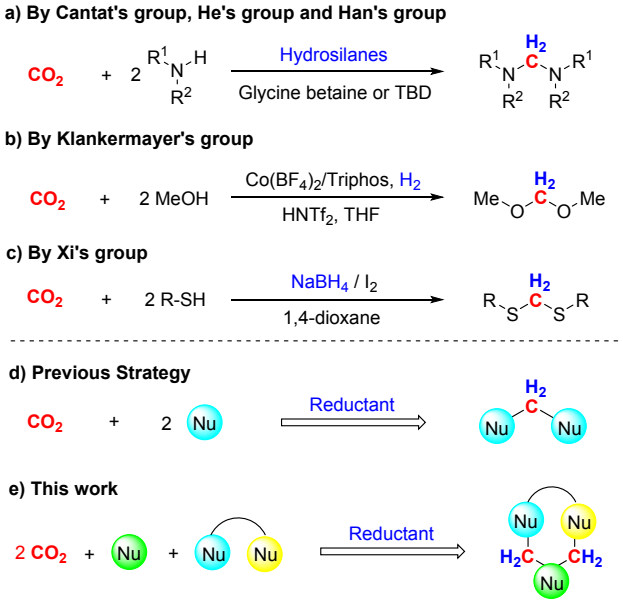


Abstract: One-pot methylenation-cyclization employing two molecules of CO_2 with enaminones and primary aromatic amines was discussed for the first time to access cyclized products. This 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD) and $ZnCl_2$ catalyzed procedure was characterized by the selective conversion of two molecules of CO_2 into methylene groups in a multi-component cyclization reaction. According to the computational study and control experiments, the reaction might proceed through the generation of bis(silyl)acetal, condensation of arylamine and *aza*-Diels-Alder processes. Moreover, the resulting products will probably be potential organic building-ins with adjustable photophysical properties.

■ INTRODUCTION

Carbon dioxide (CO_2) refers to a very abundant, renewable and nontoxic one-carbon (C1) source when compared with other C1 sources for producing chemicals.[1] However, the current application of CO_2 primarily emphasizes the transformation of its single molecule during a reaction. Developing effective strategies to employ bi- or multi-molecules of CO_2 during a reaction will be favorable for the CO_2 reuse. Recently, the reductive functionalization of CO_2 has aroused ever-increasing attention

worldwide. These reductive processes can achieve the formylation,[2] methylenation,[3] methylation,[4] etc.[5] of nucleophiles in a controllable manner. The oxidation state of carbon in CO_2 can reduce to +II, 0 or -II valence state *via* 2-, 4- or 6-electron reduction, respectively.[6] However, given that the reduction of the C^0 species (i.e., formaldehyde) to C^{-II} species (i.e., methylamine, methanol) is usually more rapid than that of C^{+II} (i.e., formamide, formic acid) to C^0 species, it is challenging to isolate or trap the C^0 species.[6a,7]



Scheme 1. CO_2 methylenation reactions

In recent years, great effort has been devoted to the conversion of CO_2 for methylenation chemicals. Employing hydrosilane as reductant and CO_2 as C1 feedstock, Oestreich,[8] Piers,[9] and Berke[10] identified the formation of active bis(silyl)acetal C^0 species. In 2015, Cantat[6a] *et al*. reported an elegant 4-electron reduction of CO_2 in the presence of secondary aromatic amines to access aminals (C^0) (Scheme 1a). He[7b] and Han[11] converted CO_2 with amines to furnish formamides, aminals or methylamines controllably by tactfully using the naturally occurring glycine betaine (GB) as catalyst. In 2015, Sabo-Etienne and Bontemps's group[6d] reported a significant iron-catalyzed reduction of CO_2 into methylene group. In 2017, Klankermayer[12] *et al*. built an efficacious tailor-made molecular cobalt catalyst system to convert CO_2 into dialkoxymethane ethers (C^0) (Scheme 1b). Furthermore, CO_2 was also adopted as C1 source for the methylenation to handily achieve olefination of phosphorus ylides[13] (Xia's group), the synthesis of spiro-indolepyrrolidines[14] (Xia's group) and dithioacetals[15] (Xi's group, under distinctive

$NaBH_4/I_2$ System, Scheme 1c). In all the above studies, CO_2 was converted into methylene in a highly selective manner, whereas these CO_2 methylenation reactions almost focused on the application of single molecule of CO_2 during a reaction (Scheme 1d).

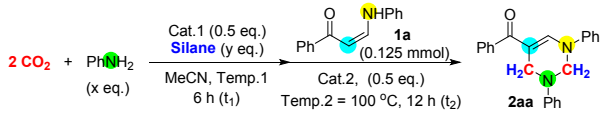
To our best knowledge, despite the mentioned achievements, the reductive methylenation reaction involving bi- or multi-molecules of CO_2 has not been reported. Accordingly, it is required to formulate feasible methylenation strategies to employ two molecules or multi-molecules of CO_2 for the formation of value-added fine chemicals. Based on our research on one-pot or tandem reactions,[16] we thought that to introduce 1,1- and asymmetric 1,3-dinucleophilic reagents may be feasible to capture two molecules of CO_2 in a cyclization reaction (Scheme 1e). Here, we wish to report our efforts in developing such an unprecedented tandem bimolecular CO_2 methylenation cyclization sequence to synthesize tetrahydropyrimidine derivatives[17], which often exhibit unique therapeutic properties (i.e. anti-inflammatory activity[18], muscarinic agonist activity[19] and antiviral activity[20]).

■ RESULTS AND DISCUSSION

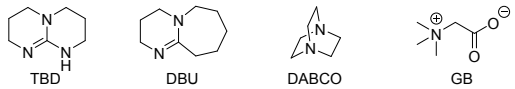
Enaminone, exhibiting high *N*-[21], *C*-[22] and *O*-nucleophilicity[23], shows a wide range of synthetic applications.[24] Hydrosilane reductant exhibits a kinetic advantage over H_2[6b] and it can be effectively activated by metal-free Lewis bases or Lewis acids.[25] Thus, with 1,5,7-triazabicyclo[4.4.0]dec-5-ene (TBD) as the catalyst and phenylsilane as the reductant, aniline and enaminone **1a** were taken as the nucleophiles to implement our one-pot tandem reaction strategy (Scheme 1e).

When toluene, 1,4-dioxane or tetrahydrofuran was adopted as the solvent, the initial trials did not yield any desired product as required. It is noteworthy that when acetonitrile was used as the solvent, tetrahydropyrimidine derivative (**2aa**) could be isolated in 52% yield (Table 1, entry 1: using 1.5 eq. of aniline). This initial result verified the feasibility of our hypothesis and laid a basis for the study of methylenation-cyclization reaction involving two molecules of CO_2. Then, the amount of aniline was screened (entries 2-4). When 2 eq. of aniline was employed, the yield of **2aa** was up-regulated to 83% (entry 2). When the amount further rose to 2.5 and 3 eq., 88% and 92%

Table 1. Optimization of the Reaction Conditions[a]



Entry	x	Silane (y eq.)	Temp.1 (°C)	Cat.1	Cat.2	Yield[b] (%)
1	1.5	$PhSiH_3$ (6)	100	TBD	$FeCl_3$	52
2	2.0	$PhSiH_3$ (6)	100	TBD	$FeCl_3$	83
3	2.5	$PhSiH_3$ (6)	100	TBD	$FeCl_3$	88
4	3.0	$PhSiH_3$ (6)	100	TBD	$FeCl_3$	92
5	2.5	$PhSiH_3$ (5)	100	TBD	$FeCl_3$	68
6	2.5	$PhSiH_3$ (4)	100	TBD	$FeCl_3$	55
7	2.5	Ph_2SiH_2 (6)	100	TBD	$FeCl_3$	55
8	2.5	Ph_3SiH (6)	100	TBD	$FeCl_3$	ND
9	2.5	Et_3SiH (6)	100	TBD	$FeCl_3$	ND
10	2.5	EtO_3SiH (6)	100	TBD	$FeCl_3$	ND
11	2.5	PMHS (6)	100	TBD	$FeCl_3$	11
12	2.5	$PhSiH_3$ (6)	80	TBD	$FeCl_3$	44
13	2.5	$PhSiH_3$ (6)	115	TBD	$FeCl_3$	96
14	2.5	$PhSiH_3$ (6)	115	TBD	$FeCl_3$	66[c]
15	2.5	$PhSiH_3$ (6)	115	TBD	$FeCl_3$	63[d]
16	2.5	$PhSiH_3$ (6)	115	TBD	-	30
17	2.5	$PhSiH_3$ (6)	115	TBD	$AlCl_3$	ND
18	**2.5**	**$PhSiH_3$ (6)**	**115**	**TBD**	**$ZnCl_2$**	**99**
19	2.5	$PhSiH_3$ (6)	115	TBD	$BF_3{\cdot}Et_2O$	97
20	2.5	$PhSiH_3$ (6)	115	TBD	HOTf	58
21	2.5	$PhSiH_3$ (6)	115	TBD	$AgNO_2$	77
22	2.5	$PhSiH_3$ (6)	115	-	$ZnCl_2$	ND
23	2.5	$PhSiH_3$ (6)	115	GB	$ZnCl_2$	89
24	2.5	$PhSiH_3$ (6)	115	DABCO	$ZnCl_2$	7
25	2.5	$PhSiH_3$ (6)	115	DBU	$ZnCl_2$	26
26	2.5	$PhSiH_3$ (6)	115	Cs_2CO_3	$ZnCl_2$	92
27	2.5	$PhSiH_3$ (6)	115	TBD (0.2 eq.)	$ZnCl_2$ (0.2 eq.)	98[e]



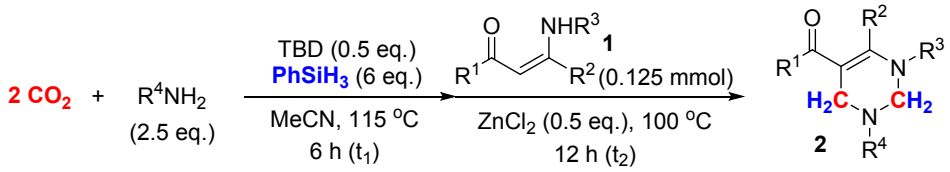
[a] $ZnCl_2$ (0.5 mol/L in THF) was used for the corresponding reactions (entries 18 and 22-26). [b] Isolated yield, ND = no detected. [c] Temp.2 = 80 °C. [d] Temp.2 = 120 °C. [e] t_1 = 12 h, t_2 = 24 h.

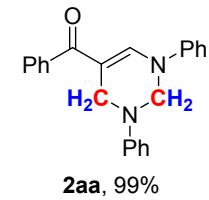
yields were achieved, separately (entries 3 and 4). According to these results (entries 1-4), the excess (>2.0 eq.) amine could facilitate this reaction. Thus, 2.5 eq. of aniline was ascertained to use for subsequent investigations. Subsequently, the amount of phenylsilane was investigated. When the amount of phenylsilane dropped from 6 eq. to 5 or 4 eq., the yield of **2aa** was down-regulated significantly (entries 5 and 6). Other silanes (i.e. Ph_2SiH_2, Ph_3SiH, Et_3SiH, EtO_3SiH and polymethylhydrosiloxane (PMHS)), were also investigated, whereas no better results were achieved (entries 7-11). The reaction temperature was found to be susceptible for the reaction. When the temperature of the first step was lowered to 80 ℃, the yield of **2aa** declined to 44% (entry 12). When

the reaction temperature was risen to 115 ℃, a better yield was obtained (entry 13, 96%). However, for the temperature of the second step, whether it rose or lowered, the yields of **2aa** would be down-regulated observably (entries 14 and 15). Note that without $FeCl_3$, only 30% yield of **2aa** was obtained (entry 16). This result suggested that a Lewis acid catalyst might be critical for the cyclization process. Accordingly, different Lewis or Brønsted acid catalysts were investigated (entries, 17-21). $ZnCl_2$ was found as the optimal catalyst to prepare the desired **2aa** in a near-quantitative yield (entry 18, 99%). An excellent yield of **2aa** (97%) could also be provided by using $BF_3{\cdot}Et_2O$ (entry 19). Lastly, the catalyst for the first step was investigated. No **2aa** was detected without TBD, revealing that a proper catalyst is vital (entry 22). Other catalysts (i.e. glycine betaine (GB), DABCO, DBU and Cs_2CO_3) were also investigated, whereas no better results were achieved (entries, 23-26). It is worth noting that when the amount of TBD and $ZnCl_2$ dropped from 0.5 eq. to 0.2 eq. (TBD: 3.5 mg), **2aa** could also be obtained in 98% yield (entry 27: it will take longer, t_1 = 12 h, t_2 = 24 h).

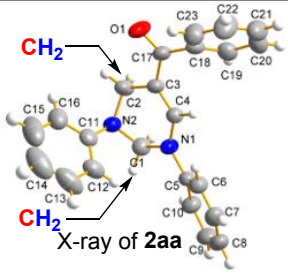
Under the optimal reaction conditions ascertained (Table 1, entry 18), the substrate scope was then examined (Table 2). This method was found to be applicable to a wide substituted enaminone and aromatic amine. First, the electronic effect of the substituent R^1 was investigated (**2aa**-**2ah**). The substrates with electron-donating (e.g., **2ab**, R^1 = 3,4,5-trimethoxyphenyl, 95%; **2ac**, R^1 = *p*-OMePh, 99%) or electron-withdrawing (e.g., **2ah**, R^1 = *p*-NO_2Ph, 94%) groups were all tolerable to furnish corresponding products in excellent yields. When R^1 was heteroaryl substituent (e.g., 2-furanyl) the corresponding **2ai** was formed in 94% yield. 2-Naphthyl and sterically hindered 1-naphthyl were also well tolerated to afford **2aj** and **2ak** in excellent yields. It is noteworthy that when R^1 was ethoxy, the corresponding product **2al** could be obtained in 65% yield, and exhibits obvious fluorescent properties[26]. **2al** could also be hydrolyzed to generate the corresponding carboxylic acid **2al'** in 75% yield (for the details, see Experimental Section). Besides, alkyl substituent (i.e. n-pentyl) also fitted the standard reaction conditions, furnishing **2am** in 72% yield. Next, the R^2 substituents were examined (**2an**-**2aq**). Good yields of the corresponding tetrahydropyrimidines could be isolated irrespective of the presence of electron-donating (**2an**, R^2 = *p*-$MeOC_6H_4$, 82%) or electron-withdrawing (**2ap**, R^2 = *p*-ClC_6H_4, 75%)

Table 2. The scope of the reaction[a]

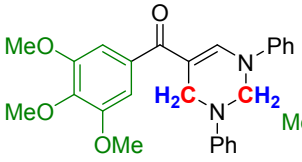




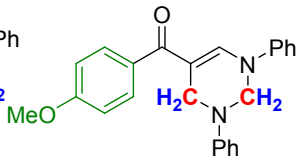
2aa, 99%



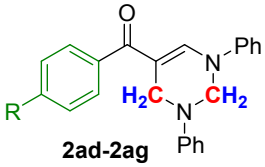
X-ray of **2aa**



2ab, 95%

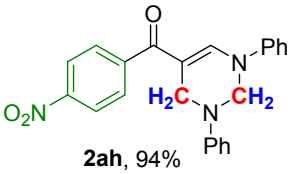


2ac, 99%

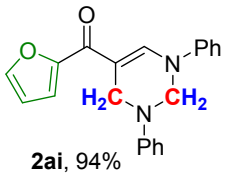


2ad-2ag

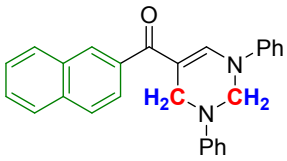
2ad, R = ^{t}Bu, 99%
2ae, R = F, 99%
2af, R = Cl, 91%
2ag, R = Br, 93%



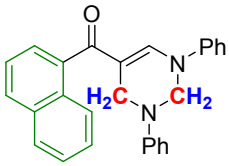
2ah, 94%



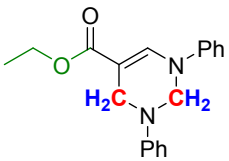
2ai, 94%



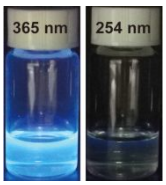
2aj, 94%



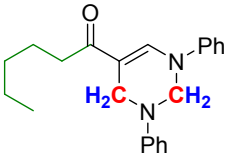
2ak, 93%



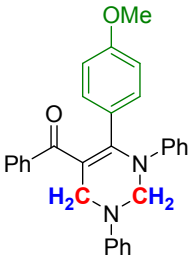
2al, 65%



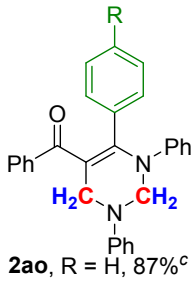
Fluorescent images[d] of **2al** in THF



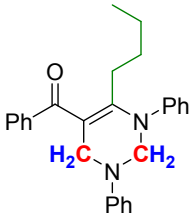
2am, 72%



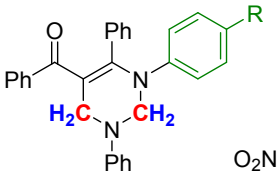
2an, 82%[b]



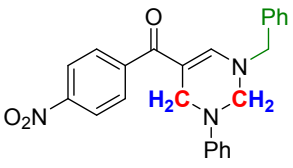
2ao, R = H, 87%[c]
2ap, R = Cl, 75%[b]



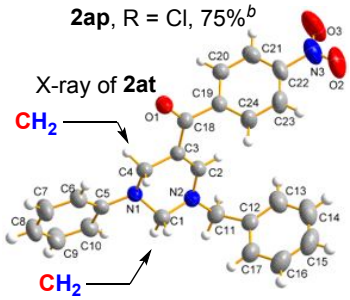
2aq, 67%[c]

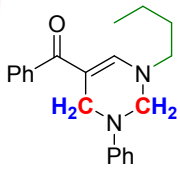


2ar, R = OMe, 85%[c]
2as, R = Cl, 82%[c]

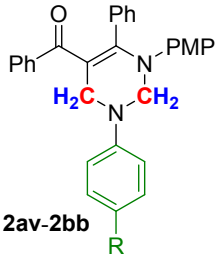


2at, 60%[b]



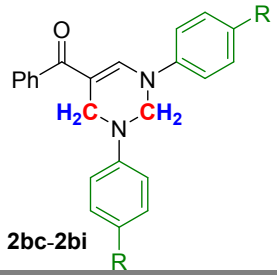


2au, 50%[b]



2av-2bb

PMP = *p*-methoxyphenyl
2av, R = OMe, 89%[c]
2aw, R = ^{t}Bu, 86%[c]
2ax, R = Et, 86%[c]
2ay, R = Me, 89%[c]
2az, R = F, 87%[c]
2ba, R = Cl, 83%[c]
2bb, R = Br, 78%[c]



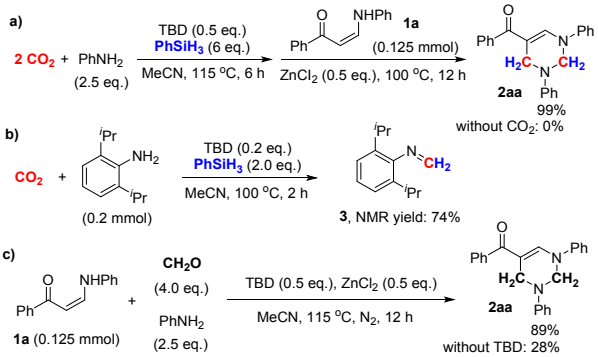
2bc-2bi

2bc, R = OMe, 80%
2bd, R = ^{t}Bu, 90%[c]
2be, R = Et, 97%
2bf, R = Me, 99%
2bg, R = F, 88%
2bh, R = Cl, 83%[c]
2bi, R = Br, 87%[c]

[a] Yields are of isolated products. [b] t_1 = 6 h, t_2 = 24 h. [c] t_1 = 12 h, t_2 = 24 h. [d] The wavelength of 360 nm and 254 nm meaning **2al** in THF under excited lights at 365 nm and 254 nm using a portable ultraviolet lamp, respectively

groups on the benzene ring. When alkyl (such as R^2 = n-butyl) instead of aryl was used, the corresponding product **2aq** could be generated in 67% yield. Then, the electronic effect of R^3 was investigated. Substrates with both *p*-OMePh and *p*-ClPh groups were suitable for the reaction, offering the desired tetrahydropyrimidines in good yields (**2ar**, 85%; **2as**, 82%). When R^3 were alkyl substituents (i.e. benzyl and n-butyl group), the corresponding *N*-alkyl product **2at** and **2au** were formed in moderate yields. For substituents R^4, the substituted phenyls bearing *p*-OMe, *p*-^{t}Bu, *p*-Et, *p*-Me, *p*-F, *p*-Cl and *p*-Br were all well tolerated (**2av**-**2bb**, 78-89%). In addition, regardless of the presence of electron-withdrawing or electron-donating groups on the aryl ring, when $R^3 = R^4$, good to excellent yields of the corresponding tetrahydropyrimidines could be obtained (**2bc**-**2bi**, 83-99%). It is worth noting that this reaction is specific to the use of primary aromatic amine. Primary alkylamine and secondary amine were not suitable for the reaction. The structure of the products was ascertained by NMR analysis and further confirmed by X-ray analysis of **2aa** and **2at**.[27]

To understand the reaction mechanism, several control experiments were performed. The reaction of CO_2, **1a** and aniline provided **2aa** in 99% yield under the optimal conditions. Without CO_2, no **2aa** was formed (Scheme 2a), suggesting that CO_2 might be the C1 source for the methylenation-cyclization reaction. When CO_2 and 2,6-diisopropylaniline were subjected to the standard conditions, the corresponding imine **3** was produced in 74% NMR yield (Scheme 2b), revealing that formaldehyde or formaldehyde equivalent might be formed as the intermediate in the reaction.[17b] To further verify this speculation, formaldehyde instead of CO_2 and phenylsilane was directly adopted, and it was found that **2aa** could be isolated in 89% yield (Scheme 2c; even without TBD, **2aa** could also be obtained in 28% yield).



Scheme 2. Control experiments

To gain more insights into the detailed reaction mechanism, density functional theory (DFT) calculations were conducted (Figure 1 and see Supporting Information for details). The addition of phenylsilane and CO_2 to generate bis(silyl)acetal **4** has been previously reported.[28] This TBD-catalyzed process is thermodynamically favorable with an energy decrease of 13.0 kcal/mol. At the outset, the nucleophilic substitution of **4** with **1a** or aniline was considered, but the corresponding calculations always led to elimination processes. This phenomenon revealed that direct formation of formaldehyde from **4** (*via* **TS1**) is more likely and is also in line with our control experiment (Scheme 2b and 2c). Formaldehyde can further undergo condensation with aniline to generate imine **8**. The condensation in the presence of TBD (*via* **TS2** and **TS3**) is kinetically favorable than that catalyzed by $ZnCl_2$ (see Fig. S1 for the calculation results of $ZnCl_2$-catalyzed condensation process). In view of the equilibrium between formaldehyde and imine **8**, they were both considered for the following addition with enaminone **1a**. The two processes are both feasible with energy barriers around 10 kcal/mol, while the addition of imine **8** (*via* **TS4** and **TS5**) is slightly superior (see Fig. S2 for the details of formaldehyde addition). Finally, we found that the elimination of **11** (*via* **TS6** and **TS7**) to afford *aza*-diene **14** followed by an *aza*-Diels-Alder reaction with **8** (*via* **TS16**) is remarkably kinetically favored.

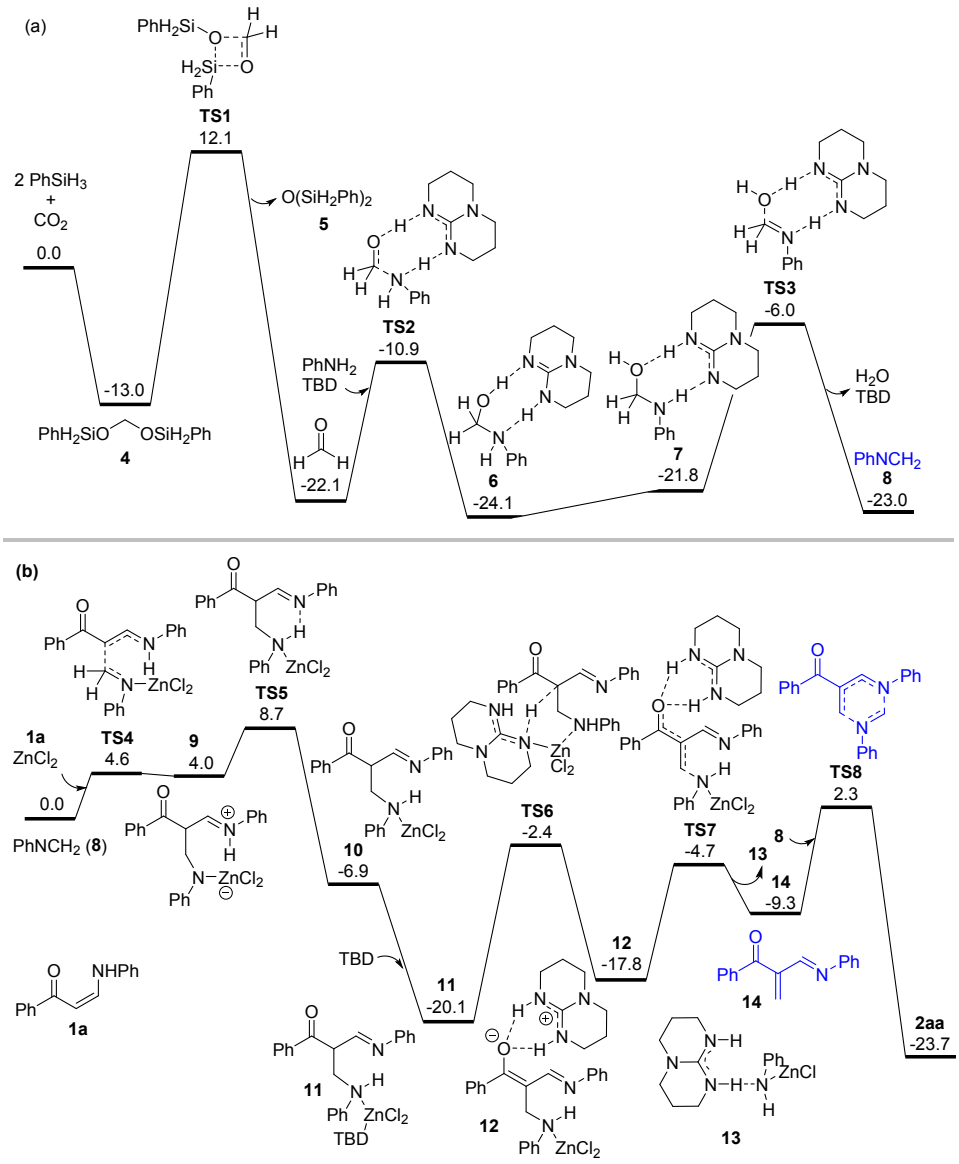


Figure 1. Calculated solution-phase Gibbs free energy changes of the cascade reaction of $PhSiH_3$, CO_2, $PhNH_2$ and enaminone **1a** *via* the nucleophilic addition of **1a** towards **8** (in kcal/mol).

Based on the above results, the following mechanism was proposed for this reaction (Figure 2). Initially, TBD-catalyzed reduction of CO_2 led to the production of bis(silyl)acetal **4** (C^0 species).[28] Formaldehyde might be formed *via* the elimination of bis(silyl)acetal species. Subsequently, the condensation of aniline with *in situ* generated bis(silyl)acetal **4** or formaldehyde led to the generation of imine **8**. The subsequent nucleophilic attack of enaminone **1a** to **8** occurred to furnish **11'**. After the elimination, *aza*-diene **14** was generated. Finally, an *aza*-Diels-Alder process between **14** and additional **8** proceed to form the final product **2aa**. This mechanism shows that two molecules of imine **8** are

utilized in this reaction, which can reasonably explain why excess (>2.0 eq.) amine is conducive (Table 1, entries 1-4).

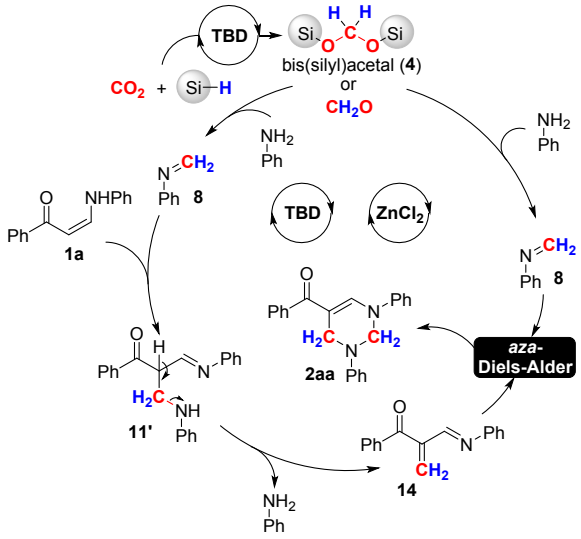


Figure 2. Proposed reaction mechanism

To interpret the relationship between photophysical properties and the molecular structures, UV-vis and fluorescent spectra of the target compounds were recorded. Figure 3a, Figure S4a and Table S2 obviously show that **2aa** in dilute THF solution (1.0×10^{-5} mol/L) possesses a strong absorption peak at 335 nm with a molar absorptivity (ε) of 4360 $L\cdot mol^{-1}\cdot cm^{-1}$. When the H atom in double bond of **2aa** was replaced by phenyl ring (**2ao**), the maximal absorption peak (λ_{max}) red shifted to 355 nm, attributed to its enlarged π-conjugated system. However, some further substituent groups on phenyl rings did not affect the resulting absorption profiles with only negligible changes happened in absorption peaks or intensities. As shown in Figure S4 and Table S2, introducing different substituted groups in phenyl rings, λ_{max} for **2aa** derivatives just alters from 333 nm to 340 nm with ε between 2820 $L\cdot mol^{-1}\cdot cm^{-1}$ and 4360 $L\cdot mol^{-1}\cdot cm^{-1}$ and λ_{max} for **2ao** derivatives from 352 nm to 358 nm with ε between 1180 $L\cdot mol^{-1}\cdot cm^{-1}$ and 1840 $L\cdot mol^{-1}\cdot cm^{-1}$ respectively, demonstrating compounds **2aa** and **2ao** are two typical kinds of optical-function organic molecules. Once one of the phenyl ring in **2aa** or **2ao** was substituted by strongly electron-deficient group (**2ah** and **2at**), electron-rich heteroaryl group (**2ai**), ethoxy (**2al**) or non-conjugated group (**2am** and **2au**), either absorption peak, intensity or its absorption profile would obviously change accordingly, *i.e.*, λ_{max} ranges from 300 nm to 358 nm with ε between 570 $L\cdot mol^{-1}\cdot cm^{-1}$ and 5270 $L\cdot mol^{-1}\cdot cm^{-1}$.

The same regularity for the fluorescent spectra was observed from three typical compounds **2aa**, **2ao** and **2al** as examples in THF (1.0×10^{-5} mol/L). As shown in Figure 3b and Table S3, both **2aa** and **2ao** exhibit moderate fluorescent intensity at 381 nm and 408 nm with normal Stokes shifts (46 nm and 53 nm), respectively. While for **2al**, multifold growth in fluorescent intensity was obtained, *i.e*., from 196.2 *a.u*. for **2aa** and 185.1 *a.u*. for **2ao** increasing to 470.6 *a.u*. for **2al**. Accordingly, photophysical behaviors of the target compounds could be efficiently controlled by designing the molecular structures. All the results suggested that some more organic materials with desirable optical properties could be derivatized from the typical compounds **2aa** and **2ao** in the future.

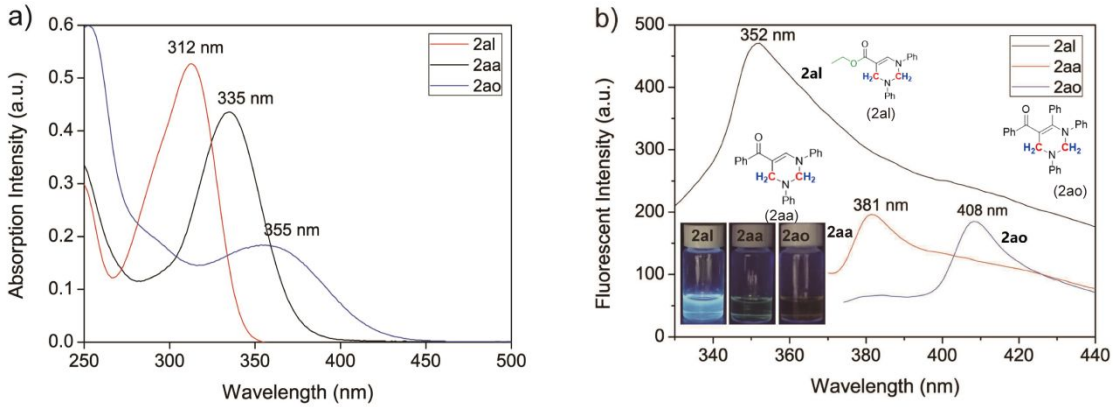


Figure 3. a) UV-vis absorption spectra and b) Fluorescent spectra of representative **2aa**, **2ao** and **2al** excited at λ_{max} in THF (1.0×10^{-5} mol/L; Insert: The colors of **2aa**, **2ao** and **2al** under excited lights at 365 nm using a portable ultraviolet lamp)

■ CONCLUSION

In summary, we have developed a tandem methylenation-cyclization reaction involving two molecules of CO_2 to access tetrahydropyrimidines. Control experiments and DFT studies revealed that this TBD and $ZnCl_2$ catalyzed reaction might proceed through the generation of bis(silyl)acetal, condensation of arylamine and *aza*-Diels-Alder processes. Potential photophysical behaviors were preliminarily investigated by UV-vis and fluorescent spectral analyses. This method realized the selective conversion of two molecules of CO_2 into methylene groups in a one-pot multi-component

cyclization reaction and effectively made the reuse of CO_2 diversified. Further investigations on the detailed reaction mechanism and potential application are in progress.

■ EXPERIMENTAL SECTION

General Methods. All reactions were carried out in carbon dioxide except noted. The $ZnCl_2$ (0.5 mol/L in THF) was purchased from Sun Chemical Technology (Shanghai) Co., Ltd. Anhydrous acetonitrile were prepared by distillation from CaH_2. Anhydrous toluene, 1,4-dioxane and tetrahydrofuran was distilled from sodium and benzophenone. Commercially, available reagents were used without further purification. Reactions were monitored by thin layer chromatography using UV light to visualize the course of reaction. Purification of reaction products was carried out by flash chromatography on silica gel (300~400 mesh). ^{1}H NMR spectra were recorded at 500 MHz, ^{13}C NMR spectra were recorded at 125 MHz, and in $CDCl_3$ or $(CD_3)_2SO$ (containing 0.03% TMS) solutions. ^{1}H NMR spectra were recorded with Me_4Si (δ = 0.00) as the internal reference and ^{13}C NMR spectra were recorded with $CDCl_3$ (δ = 77.00) or DMSO-d_6 (δ = 39.52) as the internal reference. High-resolution mass spectra were obtained using a Bruker Maxis Impact mass spectrometer with a TOF (for ESI) analyzer. Single crystal X-ray diffraction data was collected in Bruker SMARTAPEX diffractiometers with molybdenum cathodes. The enaminones **1** were prepared according to the literature methods[29] and the spectroscopic data are in agreement with that previously reported.

Computational details. Density functional theory (DFT) study was performed using Gaussian program.[30] Geometry optimization, frequency analysis and intrinsic reaction coordinates (IRC) analysis[31] were performed with B3LYP method[32], 6-31G(d) basis set and 'ultrafine' grid.[33] Based on optimized structures (no imaginary frequency for energetic minimum and only one imaginary frequency for transition states), solution-phase single point energies were calculated with B3LYP-D3(BJ) method[34], 6-311++g(d,p) basis set, SMD solvation model[35] (solvent = acetonitrile) and 'ultrafine' grid. 1.9 kcal/mol was added to the Gibbs free energies of every species to account for the change of standard state from 1 atm to 1 M at 298.15 K.[36] Thermodynamic correction obtained from frequency analysis was

added by solution-phase single point energy and 1.9 kcal/mol to get the solution-phase Gibbs free energy used for mechanistic discussion.

Synthesis and characterization of 2

Method A: To a well-dried 25 mL seal tube containing a magnetic stirring bar was added TBD (8.7 mg, 0.0625mmol). Then, the vessel was evacuated and refilled with CO_2 for five times. Under a stream of CO_2, to this vessel were added arylamine (0.3125 mmol), acetonitrile (1.5 mL) and $PhSiH_3$ (91 μL, 0.75 mmol). Then the vessel was sealed at atmospheric pressure of CO_2 (1 atm) and the resulting mixture was stirred in a 115 °C oil bath for 6 h (t_1). After cooling the reaction mixture to ambient temperature, **1** (0.125 mmol) and $ZnCl_2$ (125 μL, 0.5 mol/L in THF, 0.0625 mmol) were added under a stream of CO_2. Subsequently, the vessel was sealed and heated in a 100 °C oil bath for 12 h (t_2). The reaction could be monitored by TLC analysis. The resulting mixture was concentrated under reduced pressure and subjected to column chromatography for purification directly, using petroleum ether/ethyl acetate (3:1-15:1) as the eluent.

Method B: t_1 = 6 h, t_2 = 24 h; **Method C**: t_1 = 12 h, t_2 = 24 h.

(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2aa)***. Compound **2aa** was prepared in 99% yield (42 mg) according to the general procedure (Method A). Yellow solid; mp 134-137 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.56-7.52 (m, 3H), 7.46-7.43 (m, 1H), 7.41-7.38 (m, 2H), 7.36-7.32 (m, 2H), 7.24-7.22 (m, 2H), 7.15-7.12 (m, 1H), 6.99 (d, *J* = 7.9 Hz, 2H), 6.95-6.90 (m, 3H), 5.16 (s, 2H), 4.51 (s, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 193.4, 148.4, 146.0, 143.9, 139.5, 130.3, 129.8, 129.3, 128.4, 128.2, 124.5, 121.2, 118.5, 117.8, 110.8, 65.5, 47.1; IR (KBr): 3059, 2924, 1566, 1494, 1407, 1257, 998, 695 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{21}N_2O$ $[M+H]^+$: 341.1648, found: 341.1653.

(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(3,4,5-trimethoxyphenyl)methanone ***(2ab)***. Compound **2ab** was prepared in 95% yield (51 mg) according to the general procedure (Method A). Yellow solid; mp 107-109 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.60 (s, 1H), 7.37-7.34 (m, 2H) 7.24-7.23

(m, 2H), 7.16-7.13 (m, 1H), 6.99 (d, J = 8.0 Hz, 2H), 6.95 (d, J = 7.8 Hz, 2H), 6.93-6.90 (m, 1H), 6.80 (s, 2H), 5.16 (s, 2H), 4.49 (s, 2H), 3.87 (s, 3H), 3.86 (s, 6H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 192.6, 152.9, 148.4, 145.6, 143.8, 140.0, 135.0, 129.9, 129.3, 124.6, 121.2, 118.4, 117.8, 110.5, 105.9, 65.4, 60.9, 56.3, 47.1; IR (KBr): 2936, 1654, 1494, 1460, 1410, 1237, 764, 696, 632 cm^{-1}; HRMS (ESI) calcd for $C_{26}H_{27}N_2O_4$ $[M+H]^+$: 431.1965, found: 431.1960.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(4-methoxyphenyl)methanone (**2ac**)*. Compound **2ac** was prepared in 99% yield (46 mg) according to the general procedure (Method A). Yellow solid; mp 119-121 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.57-7.53 (m, 3H), 7.35-7.32 (m, 2H), 7.24-7.21 (m, 2H), 7.14-7.11 (m, 1H), 6.98 (d, J = 7.9 Hz, 2H), 6.94 (d, J = 7.8 Hz, 2H), 6.91-6.88 (m, 3H), 5.15 (s, 2H), 4.49 (s, 2H), 3.83 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 192.5, 161.5, 148.5, 145.0, 144.0, 132.0, 130.5, 129.8, 129.3, 124.2, 121.1, 118.4, 117.8, 113.4, 110.9, 65.4, 55.3, 47.2; IR (KBr): 2988, 2971, 2901, 1580, 1406, 1250, 1066, 761, 702 cm^{-1}; HRMS (ESI) calcd for $C_{24}H_{23}N_2O_2$ $[M+H]^+$: 371.1754, found: 371.1748.

*(4-(tert-butyl)phenyl)(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)methanone (**2ad**)*. Compound **2ad** was prepared in 99% yield (49 mg) according to the general procedure (Method A). Yellow solid; mp 144-147 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.56 (s, 1H), 7.51 (d, J = 8.3 Hz, 2H), 7.40 (d, J = 8.3 Hz, 2H), 7.36-7.33 (m, 2H), 7.24-7.21 (m, 2H), 7.14-7.11 (m, 1H), 6.99-6.95 (m, 4H), 6.91-6.88 (m, 1H), 5.15 (s, 2H), 4.49 (s, 2H), 1.32 (s, 9H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.2, 153.7, 148.5, 145.5, 144.1, 136.7, 129.8, 129.3, 128.4, 125.1, 124.4, 121.1, 118.7, 117.8, 110.9, 65.5, 47.1, 34.8, 31.2; IR (KBr): 2971, 2901, 1571, 1496, 1405, 1255, 1066, 884, 759, 703 cm^{-1};HRMS (ESI) calcd for $C_{27}H_{29}N_2O$ $[M+H]^+$: 397.2274, found: 397.2272.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(4-fluorophenyl)methanone (**2ae**)*. Compound **2ae** was prepared in 99% yield (44 mg) according to the general procedure (Method A). Yellow solid; mp 123-127 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.58-7.55 (m, 2H), 7.48 (s, 1H), 7.37-7.34 (m, 2H), 7.26-7.22 (m, 2H), 7.16-7.13 (m, 1H), 7.09-7.06 (m, 2H), 6.99-6.90 (m, 5H), 5.16 (s, 2H), 4.49 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 191.9, 164.0 (d, J_{C-F} = 248.9 Hz), 148.4, 145.8, 143.9, 135.6 (d, J_{C-}

$_F$ = 3.2 Hz), 130.6 (d, J_{C-F} = 8.5 Hz), 129.9, 129.3, 124.6, 121.2, 118.5, 117.8, 115.2 (d, J_{C-F} = 21.4 Hz), 110.7, 65.5, 47.1; IR (KBr): 2924, 2852, 1578, 1496, 1258, 759, 696 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{20}FN_2O$ $[M+H]^+$: 359.1554, found: 359.1555.

*(4-chlorophenyl)(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)methanone (**2af**)*. Compound **2af** was prepared in 91% yield (43 mg) according to the general procedure (Method A). Yellow solid; mp 138-141 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.50-7.46 (m, 3H), 7.37-7.33 (m, 4H), 7.22 (d, J = 7.6 Hz, 2H), 7.16-7.13 (m, 1H), 6.98-6.89 (m, 5H), 5.15 (s, 2H), 4.48 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 191.8, 148.3, 145.9, 143.8, 137.8, 136.4, 129.9, 129.8, 129.3, 128.4, 124.7, 121.2, 118.6, 117.8, 110.6, 65.5, 47.0; IR (KBr): 2914, 1572, 1498, 1396, 1090, 884, 758, 693 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{20}ClN_2O$ $[M+H]^+$: 375.1259, found: 375.1254.

*(4-bromophenyl)(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)methanone (**2ag**)*. Compound **2ag** was prepared in 93% yield (49 mg) according to the general procedure (Method A). Yellow solid; mp 127-130 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.53 (d, J = 8.4 Hz, 2H), 7.46 (s, 1H), 7.42 (d, J = 8.4 Hz, 2H), 7.37-7.34 (m, 2H), 7.25-7.22 (m, 2H), 7.17-7.14 (m, 1H), 6.98-6.90 (m, 5H), 5.15 (s, 2H), 4.48 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 191.9, 148.3, 146.0, 143.8, 138.3, 131.4, 130.0, 129.9, 129.3, 124.8, 124.7, 121.3, 118.6, 117.8, 110.6, 65.5, 47.0; IR (KBr): 3062, 2910, 1569, 1498, 1406, 1257, 1146, 877, 763, 695 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{20}BrN_2O$ $[M+H]^+$: 419.0754, found: 419.0749.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(4-nitrophenyl)methanone (**2ah**)*. Compound **2ah** was prepared in 94% yield (45 mg) according to the general procedure (Method A). Yellow solid; mp 152-155 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 8.25 (d, J = 8.7 Hz, 2H), 7.68-7.67 (m, 2H), 7.39 (s, 1H), 7.38-7.34 (m, 2H), 7.27-7.24 (m, 2H), 7.20-7.17 (m, 1H), 6.98-6.92 (m, 5H), 5.18 (s, 2H), 4.51 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 190.6, 148.7, 148.2, 146.8, 145.4, 143.6, 130.0, 129.4, 129.2, 125.3, 123.5, 121.5, 118.9, 117.8, 110.5, 65.8, 46.8; IR (KBr): 3070, 2909, 1561, 1498, 1346, 847, 757, 693 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{19}N_3NaO_3$ $[M+Na]^+$: 408.1319, found: 408.1322.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(furan-2-yl)methanone (**2ai**)*. Compound **2ai** was prepared in 94% yield (39 mg) according to the general procedure (Method A). Yellow solid; mp 104-107 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.38 (s, 1H), 7.51 (s, 1H), 7.42-7.38 (m, 2H), 7.23-7.17 (m, 3H), 7.09-7.06 (m, 3H), 6.97 (d, *J* = 8.0 Hz, 2H), 6.90-6.87 (m, 1H), 6.48 (dd, *J* = 3.4, 1.7 Hz, 1H), 5.16 (s, 2H), 4.48 (s, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 177.9, 153.6, 148.4, 144.6, 144.4, 144.2, 129.8, 129.3, 124.6, 121.2, 118.7, 117.9, 115.9, 111.5, 110.0, 65.6, 46.9; IR (KBr): 2926, 1577, 1497, 1468, 850, 753, 693 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{18}N_2NaO_2$ $[M+Na]^+$: 353.1260, found: 353.1265.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(naphthalen-2-yl)methanone (**2aj**)*. Compound **2aj** was prepared in 94% yield (46 mg) according to the general procedure (Method A). Yellow solid; mp 142-144 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.02 (s, 1H), 7.88-7.85 (m, 3H), 7.67 (dd, *J* = 8.5, 1.5 Hz, 1H), 7.58 (s, 1H), 7.55-7.49 (m, 2H), 7.31-7.30 (m, 2H), 7.27-7.24 (m, 2H), 7.11-7.08 (m, 1H), 7.01 (d, *J* = 8.0 Hz, 2H), 6.94-6.91 (m, 3H), 5.18 (s, 2H), 4.56 (s, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 193.3, 148.5, 146.0, 143.9, 136.9, 134.2, 132.5, 129.8, 129.4, 128.8, 128.4, 128.1, 127.7, 127.2, 126.5, 125.7, 124.5, 121.2, 118.5, 117.8, 111.1, 65.5, 47.1; IR (KBr): 2924, 1576, 1561, 1494, 1239, 757, 695 cm^{-1}; HRMS (ESI) calcd for $C_{27}H_{23}N_2O$ $[M+H]^+$: 391.1805, found: 391.1801.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(naphthalen-1-yl)methanone (**2ak**)*. Compound **2ak** was prepared in 93% yield (45 mg) according to the general procedure (Method A). Yellow solid; mp 140-142 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.89-7.87 (m, 1H), 7.79-7.75 (m, 2H), 7.40-7.35 (m, 4H), 7.21-7.14 (m, 5H), 7.00-6.94 (m, 3H), 6.88-6.85 (m, 1H), 6.72 (d, *J* = 7.7 Hz, 2H), 5.07 (s, 2H), 4.54 (s, 2H); ^{13}C{^{1}H} NMR (125 MHz, CDCl3): δ 194.0, 148.3, 146.7, 143.6, 137.4, 133.7, 131.0, 129.7, 129.4, 129.3, 128.1, 126.7, 126.2, 125.8, 125.4, 124.7, 124.5, 121.2, 118.7, 117.8, 112.4, 65.7, 46.7; IR (KBr): 2919, 1618, 1572, 1492, 1405, 1249, 1202, 759, 695 cm^{-1}; HRMS (ESI) calcd for $C_{27}H_{23}N_2O$ $[M+H]^+$: 391.1805, found: 391.1799.

*ethyl 1,3-diphenyl-1,2,3,4-tetrahydropyrimidine-5-carboxylate (**2al**)*. Compound **2al** was prepared in 65% yield (25 mg) according to the general procedure (Method A). Yellow solid; mp 73-75 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.83 (s, 1H), 7.37-7.34 (m, 2H), 7.23-7.19 (m, 2H), 7.12-7.09 (m, 1H), 7.01

(d, J = 7.9 Hz, 2H), 6.93 (d, J = 8.0 Hz, 2H), 6.90-6.87 (m, 1H), 5.04 (s, 2H), 4.26 (s, 2H), 4.20 (q, J = 7.1 Hz, 2H), 1.29 (t, J = 7.1 Hz, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 166.8, 148.7, 144.2, 140.2, 129.7, 129.2, 123.5, 121.0, 117.8, 117.7, 100.0, 64.4, 59.6, 47.5, 14.5; IR (KBr): 3062, 2976, 1623, 1594, 1494, 1394, 1244, 748, 696 cm^{-1}; HRMS (ESI) calcd for $C_{19}H_{21}N_2O_2$ $[M+H]^+$: 309.1598, found: 309.1592.

*(1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)hexan-1-one (**2am**)*. Compound **2am** was prepared in 72% yield (30 mg) according to the general procedure (Method A). Yellow oil; ^1H NMR (500 MHz, $CDCl_3$): δ 7.73 (s, 1H), 7.41-7.38 (m, 2H), 7.22-7.19 (m, 2H), 7.18-7.15 (m, 1H), 7.04 (d, J = 7.8 Hz, 2H), 6.92 (d, J = 8.0 Hz, 2H), 6.89-6.86 (m, 1H), 5.07 (s, 2H), 4.31 (s, 2H), 2.52 (t, J = 7.6 Hz, 2H), 1.67-1.62 (m, 2H), 1.33-1.28 (m, 4H), 0.88 (t, J = 6.8 Hz, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 196.8, 148.5, 144.2, 141.2, 129.8, 129.2, 124.2, 121.0, 118.4, 117.7, 111.6, 65.0, 46.9, 36.0, 31.7, 25.4, 22.5, 14.0; IR (KBr): 2924, 2853, 1654, 1618, 1493, 1257, 759, 695 cm^{-1}; HRMS (ESI) calcd for $C_{22}H_{27}N_2O$ $[M+H]^+$: 335.2118, found: 335.2121.

*(6-(4-methoxyphenyl)-1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2an**)*. Compound **2an** was prepared in 82% yield (46 mg) according to the general procedure (Method B). Yellow solid; mp 126-128 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.45-7.43 (m, 2H), 7.18-7.15 (m, 2H), 7.11-7.08 (m, 1H), 7.07-6.97 (m, 6H), 6.93-6.90 (m, 1H), 6.86-6.78 (m, 5H), 6.33 (d, J = 8.7 Hz, 2H), 5.12 (s, 2H), 4.46 (s, 2H), 3.53 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 197.0, 160.0, 154.4, 147.9, 146.5, 140.3, 132.6, 130.4, 129.1, 128.9, 128.7, 128.0, 127.3, 125.9, 124.4, 119.7, 116.0, 115.9, 113.1, 70.1, 55.0, 49.5; IR (KBr): 2969, 2923, 1601, 1571, 1492, 1254, 752, 697 cm^{-1}; HRMS (ESI) calcd for $C_{30}H_{27}N_2O_2$ $[M+H]^+$: 447.2067, found: 447.2070.

*phenyl(1,3,6-triphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)methanone (**2ao**)*. Compound **2ao** was prepared in 87% yield (45 mg) according to the general procedure (Method C). Yellow solid; mp 131-135 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.45 (d, J = 7.5 Hz, 2H), 7.19-7.16 (m, 2H), 7.10-6.99 (m, 7H), 6.91-6.87 (m, 3H), 6.82-6.80 (m, 6H), 5.14 (s, 2H), 4.49 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 197.0, 154.0, 147.9, 146.3, 140.1, 135.5, 131.1, 130.6, 129.1, 128.9, 128.9, 128.7, 127.6, 127.3, 125.9,

124.5, 119.8, 116.6, 116.1, 70.3, 49.5; IR (KBr): 2970, 2923, 1615, 1567, 1490, 1210, 747, 695 cm^{-1}; HRMS (ESI) calcd for $C_{29}H_{25}N_2O$ $[M+H]^+$: 417.1961, found: 417.1965.

(6-(4-chlorophenyl)-1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2ap)***. Compound **2ap** was prepared in 75% yield (42 mg) according to the general procedure (Method B). Yellow solid; mp 141-143 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.44 (d, *J* =7.4 Hz, 2H), 7.19-7.15 (m, 3H), 7.07-7.03 (m, 4H), 7.00 (d, *J* =8.4 Hz, 2H), 6.95-6.92 (m, 1H), 6.86 (d, *J* =8.1 Hz, 2H), 6.82-6.78 (m, 5H), 5.12 (s, 2H), 4.47 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 196.8, 152.5, 147.7, 146.0, 139.9, 134.8, 134.1, 132.2, 130.9, 129.2, 128.9, 128.9, 127.9, 127.5, 125.9, 124.8, 120.0, 117.3, 116.2, 70.4, 49.5; IR (KBr): 2923, 2847, 1599, 1490, 1375, 1200, 722, 694 cm^{-1}; HRMS (ESI) calcd for $C_{29}H_{24}ClN_2O$ $[M+H]^+$: 451.1572, found: 451.1568.

(6-butyl-1,3-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2aq)***. Compound **2aq** was prepared in 67% yield (33 mg) according to the general procedure (Method C). Yellow oil; ^1H NMR (500 MHz, $CDCl_3$): δ 7.67-7.66 (m, 2H), 7.47-7.39 (m, 3H), 7.34-7.31 (m, 2H), 7.25-7.21 (m, 3H), 7.03 (d, *J* = 7.4 Hz, 2H), 6.92 (d, *J* = 8.0 Hz, 2H), 6.89-6.86 (m, 1H), 4.89 (s, 2H), 4.32 (s, 2H), 2.10 (t, *J* = 8.0 Hz, 2H), 1.14-1.08 (m, 2H), 0.75-0.68 (m, 2H), 0.45 (t, *J* = 7.3 Hz, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 196.2, 156.9, 148.2, 144.5, 142.4, 130.7, 129.3, 129.1, 128.3, 127.9, 127.3, 126.6, 120.5, 117.2, 109.3, 70.5, 49.8, 30.6, 30.6, 22.2, 13.2; IR (KBr): 2958, 2870, 1625, 1598, 1495, 1264, 754, 698 cm^{-1}; HRMS (ESI) calcd for $C_{27}H_{29}N_2O$ $[M+H]^+$: 397.2274, found: 397.2279.

(1-(4-methoxyphenyl)-3,6-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2ar)***. Compound **2ar** was prepared in 85% yield (47 mg) according to the general procedure (Method C). Yellow solid; mp 126-128 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.43-7.42 (m, 2H), 7.21-7.18 (m, 2H), 7.09-7.04 (m, 3H), 7.01-6.98 (m, 2H), 6.90 (d, *J* = 7.9 Hz, 2H), 6.82-6.80 (m, 4H), 6.75-6.72 (m, 2H), 6.58-6.55 (m, 2H), 5.06 (s, 2H), 4.48 (s, 2H), 3.64 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 197.0, 156.6, 155.1, 148.0, 140.4, 139.5, 135.6, 131.2, 130.4, 129.2, 128.9, 128.8, 127.5, 127.4, 127.3, 119.9, 116.2, 115.7, 113.9, 70.7, 55.2, 49.4; IR (KBr): 2928, 1600, 1562, 1509, 1373, 1249, 771, 693 cm^{-1}; HRMS (ESI) calcd for $C_{30}H_{27}N_2O_2$ $[M+H]^+$: 447.2067, found: 447.2070.

(1-(4-chlorophenyl)-3,6-diphenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2as)***. Compound **2as** was prepared in 82% yield (46 mg) according to the general procedure (Method C). Yellow solid; mp 148-152 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.47 (d, *J* = 7.3 Hz, 2H), 7.20-7.17 (m, 2H), 7.12-7.09 (m, 1H), 7.06-6.98 (m, 6H), 6.88-6.81 (m, 6H), 6.71 (d, *J* = 8.7 Hz, 2H), 5.10 (s, 2H), 4.48 (s, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 197.0, 153.0, 147.7, 145.1, 139.7, 135.3, 131.0, 130.8, 129.8, 129.2, 129.1, 128.9, 128.8, 127.8, 127.4, 127.0, 120.2, 117.4, 116.3, 70.6, 49.5; IR (KBr): 2925, 1581, 1566, 1490, 1417, 1279, 761, 699 cm^{-1}; HRMS (ESI) calcd for $C_{29}H_{24}ClN_2O$ $[M+H]^+$: 451.1572, found: 451.1575.

(1-benzyl-3-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(4-nitrophenyl)methanone ***(2at)***. Compound **2at** was prepared in 60% yield (30 mg) according to the general procedure (Method B). Yellow solid; mp 128-131 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 8.21 (d, *J* =8.3 Hz, 2H), 7.61 (d, *J* =8.3 Hz, 2H), 7.31-7.30 (m, 3H), 7.23-7.20 (m, 2H), 7.11 (s, 1H), 7.07-7.06 (m, 2H), 6.93-6.90 (m, 1H), 6.87 (d, *J* = 8.0 Hz, 2H), 4.61 (s, 2H), 4.35 (s, 2H), 4.31 (s, 2H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 189.3, 151.3, 148.3, 148.2, 146.0, 134.7, 129.2, 129.0, 129.0, 128.4, 127.4, 123.3, 121.2, 117.7, 106.7, 65.2, 58.2, 45.2; IR (KBr): 2926, 2799, 1627, 1560, 1519, 1344, 1238, 750, 703 cm^{-1}; HRMS (ESI) calcd for $C_{24}H_{22}N_3O_3$ $[M+H]^+$: 400.1656, found: 400.1661.

(1-butyl-3-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2au)***. Compound **2au** was prepared in 50% yield (20 mg) according to the general procedure (Method B). Yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.49-7.47 (m, 2H), 7.41-7.36 (m, 3H), 7.30-7.27 (m, 2H), 7.03 (d, *J* = 9.5 Hz, 3H), 6.94-9.91 (m, 1H), 4.64 (s, 2H), 4.35 (s, 2H), 3.09 (t, *J* = 7.1 Hz, 2H), 1.45-1.39 (m, 2H), 1.20-1.13 (m, 2H), 0.83 (t, *J* = 7.3 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 191.8, 151.1, 148.7, 140.2, 129.6, 129.2, 128.3, 128.0, 121.1, 118.0, 105.7, 65.6, 54.2, 45.6, 30.9, 19.5, 13.5; IR (KBr): 2928, 1655, 1599, 1553, 1496, 1133, 757, 699 cm^{-1}; HRMS (ESI) calcd for $C_{21}H_{25}N_2O$ $[M+H]^+$: 321.1961, found: 321.1963.

(1,3-bis(4-methoxyphenyl)-6-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2av)***. Compound **2av** was prepared in 89% yield (53 mg) according to the general procedure (Method C).

Yellow solid; mp 138-140 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.41-7.40 (m, 2H), 7.07-6.96 (m, 5H), 6.91 (d, *J* = 9.0 Hz, 2H), 6.79-6.76 (m, 5H), 6.66 (d, *J* = 8.9 Hz, 2H), 6.52 (d, *J* = 8.9 Hz, 2H), 4.98 (s, 2H), 4.44 (s, 2H), 3.73 (s, 3H), 3.62 (s, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 197.0, 156.5, 154.8, 154.0, 142.1, 140.5, 139.5, 135.6, 131.2, 130.2, 128.8, 128.7, 127.5, 127.4, 127.2, 118.7, 115.1, 114.5, 113.8, 72.4, 55.5, 55.1, 50.3; IR (KBr): 2933, 2835, 1620, 1491, 1443, 1364, 1037, 769, 695 cm^{-1}; HRMS (ESI) calcd for $C_{31}H_{29}N_2O_3$ $[M+H]^+$: 477.2173, found: 477.2169.

(4-(tert-butyl)phenyl)-1-(4-methoxyphenyl)-6-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2aw)***. Compound **2aw** was prepared in 86% yield (54 mg) according to the general procedure (Method C). Yellow solid; mp 154-156 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42 (d, *J* = 7.4 Hz, 2H), 7.22 (d, *J* = 8.6 Hz, 2H), 7.08-7.05 (m, 3H), 7.00-6.97 (m, 2H), 6.85 (d, *J* = 8.6 Hz, 2H), 6.81-6.80 (m, 3H), 6.72 (d, *J* = 8.8 Hz, 2H), 6.54 (d, *J* = 8.8 Hz, 2H), 5.02 (s, 2H), 4.46 (s, 2H), 3.63 (s, 3H), 1.26 (s, 9H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 197.1, 156.5, 155.1, 145.6, 142.8, 140.4, 139.6, 135.7, 131.2, 130.4, 128.9, 128.8, 127.5, 127.5, 127.3, 125.9, 116.1, 115.9, 113.8, 71.2, 55.2, 49.6, 33.9, 31.4; IR (KBr): 2953, 2925, 2854, 1561, 1508, 1390, 1039, 769, 694 cm^{-1}; HRMS (ESI) calcd for $C_{34}H_{35}N_2O_2$ $[M+H]^+$: 503.2693, found: 503.2695.

(4-ethylphenyl)-1-(4-methoxyphenyl)-6-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2ax)***. Compound **2ax** was prepared in 86% yield (51 mg) according to the general procedure (Method C). Yellow solid; mp 146-147 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42 (d, *J* = 7.2 Hz, 2H), 7.08-6.97 (m, 7H), 6.85-6.79 (m, 5H), 6.71 (d, *J* = 8.9 Hz, 2H), 6.55 (d, *J* = 8.9 Hz, 2H), 5.02 (s, 2H), 4.46 (s, 2H), 3.64 (s, 3H), 2.54 (q, *J* = 7.6 Hz, 2H), 1.17 (t, *J* = 7.6 Hz, 3H); ^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$): δ 197.0, 156.5, 155.0, 145.9, 140.4, 139.6, 136.0, 135.7, 131.2, 130.3, 128.9, 128.8, 128.5, 127.5, 127.2, 116.6, 115.7, 113.8, 71.3, 55.2, 49.7, 27.9, 15.9; IR (KBr): 2960, 2926, 1617, 1561, 1507, 1364, 1246, 771, 696 cm^{-1}; HRMS (ESI) calcd for $C_{32}H_{31}N_2O_2$ $[M+H]^+$: 475.2380, found: 475.2386.

(4-methoxyphenyl)-6-phenyl-3-(p-tolyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone ***(2ay)***. Compound **2ay** was prepared in 89% yield (51 mg) according to the general procedure (Method C). Yellow solid; mp 139-143 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42-7.40 (m, 2H), 7.07-6.97 (m, 7H),

6.83-6.78 (m, 5H), 6.73-6.70 (m, 2H), 6.56-6.53 (m, 2H), 5.01 (s, 2H), 4.45 (s, 2H), 3.63 (s, 3H), 2.23 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 197.0, 156.5, 155.0, 145.7, 140.5, 139.5, 135.7, 131.2, 130.3, 129.6, 129.4, 128.9, 128.7, 127.5, 127.4, 127.2, 116.6, 115.6, 113.8, 71.2, 55.1, 49.7, 20.4; IR (KBr): 3059, 2918, 2836, 1602, 1491, 1365, 1243, 773, 694 cm^{-1}; HRMS (ESI) calcd for $C_{31}H_{29}N_2O_2$ $[M+H]^+$: 461.2224, found: 461.2227.

*(3-(4-fluorophenyl)-1-(4-methoxyphenyl)-6-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2az**)*. Compound **2az** was prepared in 87% yield (50 mg) according to the general procedure (Method C). Yellow solid; mp 126-129 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42-7.41 (m, 2H), 7.08-6.97 (m, 5H), 6.89-6.87 (m, 4H), 6.81-6.78 (m, 3H), 6.67-6.65 (m, 2H), 6.55-6.53 (m, 2H), 5.01 (s, 2H), 4.45 (s, 2H), 3.62 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 197.0, 157.3 (d, J_{C-F} = 237.8 Hz), 156.6, 154.8, 144.5 (d, J_{C-F} = 2.2 Hz), 140.3, 139.4, 135.5, 131.2, 130.4, 128.9, 128.8, 127.5, 127.4, 127.2, 118.3 (d, J_{C-F} = 7.6 Hz), 115.6 (d, J_{C-F} = 22.1 Hz), 115.0, 113.9, 71.9, 55.2, 55.1; IR (KBr): 2924, 2853, 1599, 1512, 1366, 1247, 772, 694 cm^{-1}; HRMS (ESI) calcd for $C_{30}H_{26}FN_2O_2$ $[M+H]^+$: 465.1973, found: 465.1968.

*(4-chlorophenyl)-1-(4-methoxyphenyl)-6-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2ba**)*. Compound **2ba** was prepared in 83% yield (50 mg) according to the general procedure (Method C). Yellow solid; mp 124-127 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42 (d, J = 7.2 Hz, 2H), 7.12 (d, J = 8.9 Hz, 2H), 7.09-6.97 (m, 5H), 6.81-6.78 (m, 5H), 6.71 (d, J = 8.9 Hz, 2H), 6.56 (d, J = 8.9 Hz, 2H), 5.03 (s, 2H), 4.46 (s, 2H), 3.63 (s, 3H); $^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$): δ 196.9, 156.7, 155.0, 146.6, 140.2, 139.3, 135.4, 131.2, 130.4, 129.0, 128.9, 128.9, 127.5, 127.3, 127.3, 124.6, 117.4, 115.3, 114.0, 70.5, 55.2, 49.5; IR (KBr): 2926, 1595, 1555, 1508, 1366, 1245, 1095, 771, 694 cm^{-1}; HRMS (ESI) calcd for $C_{30}H_{26}ClN_2O_2$ $[M+H]^+$: 481.1677, found: 481.1671.

*(3-(4-bromophenyl)-1-(4-methoxyphenyl)-6-phenyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bb**)*. Compound **2bb** was prepared in 78% yield (51 mg) according to the general procedure (Method C). Yellow solid; mp 139-142 °C; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.42 (d, J = 7.3 Hz, 2H), 7.27-7.25 (m, 2H), 7.09-6.98 (m, 5H), 6.82-6.79 (m, 3H), 6.75-6.71 (m, 4H), 6.57 (d, J =

8.9 Hz, 2H), 5.03 (s, 2H), 4.45 (s, 2H), 3.64 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 196.9, 156.7, 155.2, 147.2, 140.2, 139.3, 135.4, 131.9, 131.2, 130.5, 128.9, 128.9, 127.5, 127.3, 127.3, 117.7, 115.4, 114.0, 111.8, 70.3, 55.2, 49.4; IR (KBr): 2834, 1589, 1562, 1508, 1493, 1377, 1247, 1032, 769, 723, 694 cm^{-1};HRMS (ESI) calcd for $C_{30}H_{26}BrN_2O_2$ $[M+H]^+$: 525.1172, found: 525.1177.

*(1,3-bis(4-methoxyphenyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bc**)*. Compound **2bc** was prepared in 80% yield (40 mg) according to the general procedure (Method A). Yellow solid; mp 147-149 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.54-7.53 (m, 2H), 7.44-7.37 (m, 4H), 6.97-6.94 (m, 2H), 6.87-6.83 (m, 4H), 6.81-6.79 (m, 2H), 5.01 (s, 2H), 4.41 (s, 2H), 3.77 (s, 3H), 3.75 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.1, 157.0, 154.5, 146.9, 142.3, 139.8, 137.6, 130.1, 128.4, 128.1, 121.0, 119.8, 114.9, 114.5, 109.5, 67.5, 55.5, 55.5, 47.4; IR (KBr): 2928, 2833, 1562, 1509, 1441, 1245, 1034, 872, 702 cm^{-1}; HRMS (ESI) calcd for $C_{25}H_{25}N_2O_3$ $[M+H]^+$: 401.1860, found: 401.1863.

*(1,3-bis(4-(tert-butyl)phenyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bd**)*. Compound **2bd** was prepared in 90% yield (51 mg) according to the general procedure (Method C). Yellow solid; mp 144-146 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.54-7.50 (m, 3H), 7.43-7.34 (m, 6H), 7.25-7.24 (m, 1H), 6.93 (d, J = 8.8 Hz, 2H), 6.89 (d, J = 8.7 Hz, 2H), 5.10 (s, 2H), 4.46 (s, 2H), 1.29 (s, 9H), 1.27 (s, 9H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.2, 147.6, 146.3, 146.1, 143.9, 141.3, 139.7, 130.1, 128.4, 128.1, 126.6, 126.1, 118.3, 117.6, 110.4, 65.6, 47.1, 34.4, 34.0, 31.4, 31.3; IR (KBr): 2960, 2866, 1591, 1568, 1517, 1364, 1257, 1147, 878, 828, 699 cm^{-1}; HRMS (ESI) calcd for $C_{31}H_{37}N_2O$ $[M+H]^+$: 453.2900, found: 453.2906.

*(1,3-bis(4-ethylphenyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2be**)*. Compound **2be** was prepared in 97% yield (48 mg) according to the general procedure (Method A). Yellow solid; mp 128-129 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.54-7.52 (m, 2H), 7.48 (s, 1H), 7.44-7.36 (m, 3H), 7.15 (d, J = 8.4 Hz, 2H), 7.07 (d, J = 8.5 Hz, 2H), 6.92 (d, J = 8.6 Hz, 2H), 6.86 (d, J = 8.5 Hz, 2H), 5.09 (s, 2H), 4.46 (s, 2H), 2.61 (q, J = 7.6 Hz, 2H), 2.56 (q, J = 7.6 Hz, 2H), 1.21 (t, J = 7.6 Hz, 3H), 1.19 (t, J = 7.6 Hz, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.3, 146.5, 146.4, 141.8, 140.8, 139.7, 137.1,

130.1, 129.1, 128.6, 128.4, 128.1, 118.8, 118.0, 110.2, 65.9, 47.2, 28.1, 27.9, 15.6, 15.5; IR (KBr): 2961, 2924, 1567, 1513, 1368, 1254, 972, 867, 719 cm^{-1}; HRMS (ESI) calcd for $C_{27}H_{29}N_2O$ $[M+H]^+$: 397.2274, found: 397.2280.

*(1,3-di-p-tolyl-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bf**)*. Compound **2bf** was prepared in 99% yield (46 mg) according to the general procedure (Method A). Yellow solid; mp 125-127 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.54-7.52 (m, 2H), 7.46 (s, 1H), 7.42-7.41 (m, 1H), 7.39-7.36 (m, 2H), 7.12 (d, J = 8.2 Hz, 2H), 7.04 (d, J = 8.3 Hz, 2H), 6.89 (d, J = 8.6 Hz, 2H), 6.83 (d, J = 8.4 Hz, 2H), 5.08 (s, 2H), 4.46 (s, 2H), 2.31 (s, 3H), 2.25 (s, 3H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.2, 146.4, 146.1, 141.6, 139.7, 134.4, 130.6, 130.3, 130.1, 129.8, 128.4, 128.1, 118.8, 118.0, 110.1, 66.0, 47.1, 20.7, 20.4; IR (KBr): 3027, 2920, 1586, 1569, 1512, 1257, 1133, 998, 806, 722 cm^{-1}; HRMS (ESI) calcd for $C_{25}H_{25}N_2O$ $[M+H]^+$: 369.1961, found: 369.1956.

*(1,3-bis(4-fluorophenyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bg**)*. Compound **2bg** was prepared in 88% yield (41 mg) according to the general procedure (Method A). Yellow solid; mp 118-120 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.55-7.54 (m, 2H), 7.47-7.39 (m, 4H), 7.04-7.01 (m, 2H), 6.94 (d, J = 6.4 Hz, 4H), 6.89-6.86 (m, 2H), 5.05 (s, 2H), 4.43 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.3, 159.8 (d, $J_{C\text{-}F}$ = 243.9 Hz), 157.8 (d, $J_{C\text{-}F}$ = 239.4 Hz), 146.1, 144.7 (d, $J_{C\text{-}F}$ = 2.4 Hz), 140.4 (d, $J_{C\text{-}F}$ = 2.7 Hz), 139.3, 130.4, 128.4, 128.2, 120.8 (d, $J_{C\text{-}F}$ = 8.2 Hz), 119.7 (d, $J_{C\text{-}F}$ = 7.8 Hz), 116.6 (d, $J_{C\text{-}F}$ = 22.7 Hz), 115.8 (d, $J_{C\text{-}F}$ = 22.2 Hz), 110.4, 67.0, 47.3; IR (KBr): 2974, 2900, 1564, 1509, 1406, 1382, 1050, 880 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{19}F_2N_2O$ $[M+H]^+$: 377.1460, found: 377.1467.

*(1,3-bis(4-chlorophenyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bh**)*. Compound **2bh** was prepared in 83% yield (42 mg) according to the general procedure (Method C). Yellow solid; mp 120-122 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.54 (d, J = 7.3 Hz, 2H), 7.47-7.39 (m, 4H), 7.30 (d, J = 8.6 Hz, 2H), 7.18 (d, J = 8.8 Hz, 2H), 6.88-6.83 (m, 4H), 5.08 (s, 2H), 4.46 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.3, 146.9, 145.1, 142.4, 139.1, 130.6, 130.0, 129.9, 129.3, 128.4, 128.3, 126.3,

119.6, 119.1, 111.1, 65.6, 47.0; IR (KBr): 2972, 2901, 1630, 1556, 1497, 1407, 1255, 1066, 879, 703 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{19}Cl_2N_2O$ $[M+H]^+$: 409.0869, found: 409.0874.

*(1,3-bis(4-bromophenyl)-1,2,3,4-tetrahydropyrimidin-5-yl)(phenyl)methanone (**2bi**)*. Compound **2bi** was prepared in 87% yield (54 mg) according to the general procedure (Method C). Yellow solid; mp 135-137 °C; ^1H NMR (500 MHz, $CDCl_3$): δ 7.54 (d, *J* = 7.1 Hz, 2H), 7.46-7.39 (m, 6H), 7.32 (d, *J* = 8.9 Hz, 2H), 6.82-6.77 (m, 4H), 5.08 (s, 2H), 4.45 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$): δ 193.3, 147.3, 145.0, 142.9, 139.1, 132.9, 132.2, 130.6, 128.4, 128.3, 119.9, 119.4, 117.5, 113.7, 111.3, 65.4, 47.0; IR (KBr): 2924, 2853, 1610, 1582, 1493, 1265, 1207, 1142, 822, 698 cm^{-1}; HRMS (ESI) calcd for $C_{23}H_{19}Br_2N_2O$ $[M+H]^+$: 496.9859, found: 496.9865.

Synthesis and characterization of 2al'

To a 25 mL Schlenk tube containing a magnetic stirring bar was added **2al** (80 mg, 0.26 mmol), ethanol (3 mL, 95%), NaOH (31.2 mg, 0.78 mmol), H_2O (9.5 μL, 0.52 mmol). The mixture was stirred in an 80 °C oil bath for about 8 h until **2al** had disappeared by TLC analysis. Then, the resulting mixture was cooled to room temperature and quenched with by saturated solution of ammonium chloride, and extracted with ethyl acetate (20 mL × 3). The combined organic layers were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduced pressure. Purification by flash chromatography on silica gel with dichloromethane/ethyl acetate = 1:2 as the eluent afforded the corresponding acid **2al'**.

*1,3-diphenyl-1,2,3,4-tetrahydropyrimidine-5-carboxylic acid (**2al'**)*. White solid; 75% yield (55 mg); mp 142-144 °C; ^1H NMR (500 MHz, DMSO-d_6): δ 11.61 (s, 1H), 7.74 (s, 1H), 7.38-7.35 (m, 2H), 7.20-7.14 (m, 4H), 7.09-7.06 (m, 1H), 6.93 (d, *J* = 8.1 Hz, 2H), 6.83-6.81 (m, 1H), 5.15 (s, 2H), 4.16 (s, 2H); $^{13}C\{^1H\}$ NMR (125 MHz, DMSO-d_6): δ 167.5, 148.6, 143.6, 139.1, 129.7, 129.1, 122.9, 120.3, 117.2, 116.9, 99.8, 63.3, 46.7; IR (KBr): 2868, 1640, 1594, 1495, 1404, 1243, 758, 690 cm^{-1}; HRMS (ESI) calcd for $C_{17}H_{17}N_2O_2$ $[M+H]^+$: 281.1285, found: 281.1288.

Observation of imine intermediate 3 under the standard conditions

According to General Method A, to a well-dried 25 mL seal tube containing a magnetic stirring bar was added TBD (5.6 mg, 0.04mmol). Then, the vessel was evacuated and refilled with CO_2 for five times. Under a stream of CO_2, to this vessel were added 2,6-diisopropylaniline (0.2 mmol), acetonitrile (1.0 mL) and $PhSiH_3$ (49 μL, 0.4 mmol). Then the vessel was sealed at atmospheric pressure of CO_2 (1 atm) and the resulting mixture was stirred in a 100 °C oil bath for 4 h. The mixture was cooled to room temperature and internal standard 1,1,2,2-tetrachloroethane (0.2 mmol, 21uL) was added. *N*-(2,6-Diisopropylphenyl) methanimine **3** was obtained in 74% NMR yield. ^{1}H NMR (500 MHz, DMSO-d_6): δ 7.77 (d, J = 17.7 Hz, 1H), 7.39 (d, J = 17.7 Hz, 1H), 7.16-6.95 (m, 3H), 2.92-2.87 (m, 2H), 1.14 (d, J = 6.9 Hz, 12H).[37]

Gram-Scale Preparation (for 2aa):

To a well-dried 500 mL seal tube containing a magnetic stirring bar was added TBD (208.8 mg, 1.5 mmol). Then, the vessel was evacuated and refilled with CO_2 for five times. Under a stream of CO_2, to this vessel were added aniline (0.68 mL, 7.5 mmol), acetonitrile (40 mL) and $PhSiH_3$ (2.2 mL, 18 mmol). Then the vessel was sealed at atmospheric pressure of CO_2 (1 atm) and the resulting mixture was stirred in a 115 °C oil bath for 10 h. After cooling the reaction mixture to ambient temperature, **1a** (0.67 g, 3 mmol) and $ZnCl_2$ (3 mL, 0.5 mol/L in THF, 1.5 mmol) were added under a stream of CO_2. Subsequently, the vessel was sealed and heated in a 100 °C oil bath for 16 h. The reaction could be monitored by TLC analysis. The resulting mixture was concentrated under reduced pressure. The resulting residue was subjected to column chromatography for purification (petroleum ether/ethyl acetate = 5:1) to give pure **2aa** (0.95 g, 93%).

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website.

^{1}H and ^{13}C NMR spectra for compounds **2** and **3**, calculated energy profile of less favored pathways, the UV-vis absorption spectra and spectral properties of compounds **2**, fluorescent spectral properties of representative **2aa**, **2ao** and **2al** (PDF)

Crystallographic details for compounds **2aa** and **2at** (CIF)

■ AUTHOR INFORMATION

Corresponding Author

*(Yulei Zhao) E-mail: zhaoyulei86@126.com

*(Zhengquan Yan) E-mail: yanzhq2008@163.com

*(Jinmao You) E-mail: jmyou6304@163.com.

*(Yuanye Jiang) E-mail: qfnu_yuanyejiang@163.com

Notes

The authors declare no competing financial interest.

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