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Construction of 2,3,4,5-tetrahydro-1,2,4-triazines *via* [4 + 2] cycloaddition of α-halogeno hydrazones to imines†

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In the presence of sodium carbonate, the [4 + 2] cycloaddition of α-halogeno hydrazones to imines proceeded readily, and furnished 2,3,4,5-tetrahydro-1,2,4-triazines in moderate to high chemical yields.

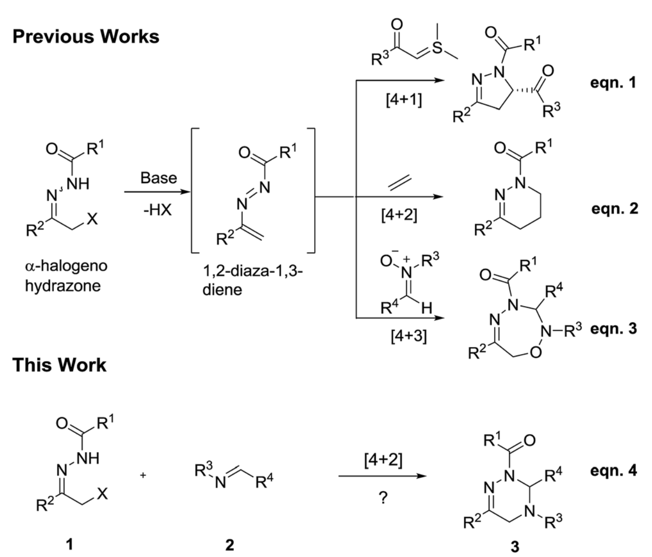
1. Introduction

α-Halogeno hydrazones represent a class of versatile and robust building blocks, which have been widely applied in the construction of structurally diverse and complex N-containing heterocycles possessing varying ring sizes. Normally, α-halogeno hydrazones can undergo [4 + 1],[1] [4 + 2][2] or [4 + 3][3] cycloadditions with structurally different dienophiles *via* the *in situ* formed 1,2-diaza-1,3-diene intermediates under basic reaction conditions. For example, in 2012, Bolm and co-workers realized the enantioselective synthesis of dihydropyrazoles by means of the [4 + 1] cycloaddition of α-halogeno hydrazones to sulphur ylides (Scheme 1, eqn. (1)).[4] In 2015, the Luo research group reported the [4 + 2] cycloaddition of α-halogeno hydrazones to simple olefins for the preparation of tetrahydropyridazines (Scheme 1, eqn (2)).[5] Recently, our research group successfully designed the [4 + 3] cycloaddition of α-halogeno hydrazones to nitrones for the preparation of 1,2,4,5-oxatriazepines (Scheme 1, eqn (3)).[6] In particular, most of the previously reported [4 + 2] cycloadditions of α-halogeno hydrazones mainly focused on the use of the differently functionalized olefins as dienophiles.[7] In addition, only three other pioneering works respectively dealt with the use of arylacetic acids,[8] methoxyallene[9] or azodicarboxylates[10] as dienophiles in the [4 + 2] cycloadditions of α-halogeno hydrazones. It is well known that the employment of imines as dienophiles in [4 + 2] cycloaddition of α-halogeno hydrazones has been fully unexplored to date. So, the development of novel [4 + 2] cycloadditions of α-halogeno hydrazones with imines is highly demanded for the synthesis of potentially bioactive heterocycles.

On the basis of the previously published elegant examples, in this work, we first attempted the novel [4 + 2] cycloaddition of α-halogeno hydrazones with synthetically useful and important imines[11] for the construction of 2,3,4,5-tetrahydro-1,2,4-triazines bearing potential biological activities[12] (Scheme 1, eqn (4)). To our delight, under the mild reaction conditions, the [4 + 2] cycloaddition of α-halogeno hydrazones with imines underwent readily, and furnished the target molecules in moderate to high chemical yields. To the best of our knowledge, such a work has not been reported in the literature so far.

2. Results and discussion

At the outset, we explored the base effects on the chemical yield of the [4 + 2] cycloaddition of α-halogeno hydrazone **1a** with imine **2a** in DCM solvent at room temperature as summarized in Table 1. Indeed, the used base affected the chemical yield of



Scheme 1 Representative cycloadditions of α-halogeno hydrazones.

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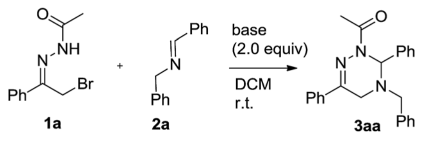
† Electronic supplementary information (ESI) available: Copies of NMR spectra for all products related to this article; X-ray single crystal structure analysis data for **3aa**. CCDC 1508810. For ESI and crystallographic data in CIF or other electronic format see DOI: 10.1039/c6ra27767e

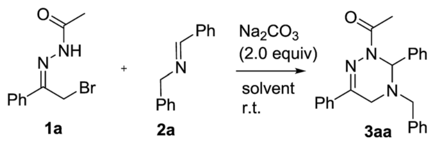
Table 1 Screening of bases[a]



Entry	Base	Time (h)	Yield[b] (%)
1	Na_2CO_3	25	44
2	K_2CO_3	25	34
3	Cs_2CO_3	25	33
4	$NaHCO_3$	36	8
5	KOH	36	13
6	MeONa	36	19
7	Et_3N	48	2
8	DBU	48	Trace

[a] Unless otherwise noted, reactions were carried out with **1a** (0.2 mmol), **2a** (0.3 mmol), base (0.4 mmol) in DCM (1.0 mL) at room temperature. [b] Isolated yield.

Table 2 Screening of solvents[a]



Entry	Solvent	Time (h)	Yield[b] (%)
1	DCE	24	54
2	THF	24	52
3	Et_2O	24	52
4	DME	24	51
5	Toluene	24	75
6	MeCN	24	35
7	MeOH	36	20
8	PhCl	24	68
9	Benzene	24	71
10[c]	Toluene	24	16
11[d]	Toluene	24	46

[a] Unless otherwise noted, reactions were carried out with **1a** (0.2 mmol), **2a** (0.3 mmol), Na_2CO_3 (0.4 mmol) in the solvent (1.0 mL) at room temperature. [b] Isolated yield. [c] 0.5 equiv. of Na_2CO_3. [d] 1.0 equiv. of Na_2CO_3.

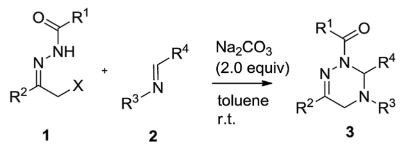
the [4 + 2] cycloaddition significantly. Using DBU as a base gave product **3aa** in a trace amount after 48 h (entry 8). The choice of $NaHCO_3$ and Et_3N as bases did not enhance the chemical yield of **3aa** dramatically (entries 4 & 7). By comparison with the former cases, the chemical yield of [4 + 2] cycloaddition increased differently by using KOH and MeONa as bases (entries 5–6). Moreover, when Na_2CO_3, K_2CO_3 and Cs_2CO_3 were examined as bases, the chemical yield of the [4 + 2] cycloaddition ranged from 33% to 44% (entries 1–3). Obviously, among all the bases screened, Na_2CO_3 performed best and delivered product **3aa** in highest chemical yield (entry 1).

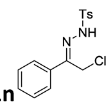
Simultaneously, by using Na_2CO_3 (2.0 equiv.) as base, we investigated the solvent effects on the chemical yield of the [4 + 2] cycloaddition of α-halogeno hydrazone **1a** with imine **2a** as shown in Table 2. Remarkably, the chemical yield of the [4 + 2] cycloaddition was largely influenced by the attempted solvents. In MeOH solvent, the [4 + 2] cycloaddition furnished product **3aa** in 20% chemical yield in 36 h (entry 7). In contrast with the former case, the chemical yield of the [4 + 2] cycloaddition increased to 35% by choosing MeCN as solvent (entries 6 *vs.* 7). As for solvents DCE, THF, Et_2O and DME, they afforded product **3aa** in similar chemical yields (entries 1–4). Finally, with the use of toluene, PhCl and benzene as solvents, the chemical yield of the [4 + 2] cycloaddition changed from 68% to 75% (entries 5 and 8–9). Therefore, Na_2CO_3 behaved most efficiently in toluene solvent, thus providing **3aa** in the highest chemical yield (entry 5). In addition, we examined other equivalent amounts of Na_2CO_3 in the [4 + 2] cycloaddition by using toluene as solvent, and found that use of 2.0 equiv. of Na_2CO_3 furnished product **3aa** in the highest chemical yield (Table 2, entries 5 *vs.* 10–11).

Subsequently, under the optimal reaction conditions, we broadened the reaction scope of the [4 + 2] cycloaddition by diversifying α-halogeno hydrazones **1** and imines **2** as outlined in Table 3. Noticeably, the chemical yield of the [4 + 2] cycloaddition highly depended on the structural nature of the used α-halogeno hydrazones **1** and imines **2**. Regarding the [4 + 2] cycloaddition with α-halogeno hydrazone **1a**, most imine substrates **2** well tolerated the structural variation of R^3 and R^4 groups, thus delivering products **3** in 62–88% chemical yields (entries 1–8 & 10–12). In contrast with the former cases, the imines **2i** and **2m** individually bearing a *para*-methoxy-substituted benzyl group or a phenyl group at R^3 position furnished products **3ai** and **3am** in the dramatically decreased chemical yields in the [4 + 2] cycloaddition with **1a** (entries 1 *vs.* 9, 1 *vs.* 13). Meanwhile, it was noted that in the [4 + 2] cycloaddition with **1a**, the regioisomers **2c–2e**, which derived from the different substitution pattern of nitro group at R^4 moiety, provided products **3ac–3ae** in the quite different chemical yields (entries 3–5).

In case of the [4 + 2] cycloaddition with **2a**, most α-halogeno hydrazones **1** could better endure the wide variation in R^1 and R^2 groups, and led to the formation of products **3** in 57–86% chemical yields (entries 14–21 & 24–26). With respect to the imines **1j** with a bulky *tert*-butyl as R^2 group and **1k** with a phenyl as R^1 group, they preferred to afford products **3** in the relatively lowered chemical yields in the [4 + 2] cycloaddition with **2a** (entries 1 *vs.* 22, 14 *vs.* 23). Generally, in the [4 + 2] cycloaddition with **2a**, the imines **1** including an electron-poor phenyl group at R^2 position usually behaved better than the imines **1** containing an electron-rich phenyl group at R^2 position, and produced products **3** in higher chemical yields (entries 15–16 *vs.* 17–20). Simultaneously, it should be addressed that α-halogeno hydrazones **1a** and **1b**, which differ from each other in X group, gave rise to the same product **3aa** in the tremendously different chemical yield in the [4 + 2] cycloaddition with **2a** (entries 1 *vs.* 14). Moreover, the [4 + 2] cycloaddition of **1f** with **2b** gave product **3fb** in 81% chemical yield (entry 27). At last, we further performed the extension of the reaction scope of the [4 + 2] cycloaddition by treating α-halogeno hydrazone **2f** with

Table 3 Extension of reaction scope[a]



Entry	1 (X, R^1, R^2)	2 (R^3, R^4)	3	Time (h)	Yield[b] (%)
1	**1a** (Br, Me, Ph)	**2a** (Bn, Ph)	**3aa**	24	75
2	**1a** (Br, Me, Ph)	**2b** (Bn, 4-$MeOC_6H_4$)	**3ab**	30	85
3	**1a** (Br, Me, Ph)	**2c** (Bn, 4-$NO_2C_6H_4$)	**3ac**	30	67
4	**1a** (Br, Me, Ph)	**2d** (Bn, 3-$NO_2C_6H_4$)	**3ad**	30	62
5	**1a** (Br, Me, Ph)	**2e** (Bn, 2-$NO_2C_6H_4$)	**3ae**	30	75
6	**1a** (Br, Me, Ph)	**2f** (Bn, 4-BrC_6H_4)	**3af**	24	88
7	**1a** (Br, Me, Ph)	**2g** (Bn, 2-naphthyl)	**3ag**	30	66
8	**1a** (Br, Me, Ph)	**2h** (Bn, 2-furyl)	**3ah**	30	80
9	**1a** (Br, Me, Ph)	**2i** (4-MeO $C_6H_4CH_2$, Ph)	**3ai**	24	29
10	**1a** (Br, Me, Ph)	**2j** (4-$FC_6H_4CH_2$, Ph)	**3aj**	24	77
11	**1a** (Br, Me, Ph)	**2k** (4-$ClC_6H_4CH_2$, Ph)	**3ak**	24	77
12	**1a** (Br, Me, Ph)	**2l** (Me, Ph)	**3al**	24	75
13	**1a** (Br, Me, Ph)	**2m** (Ph, Ph)	**3am**	36	33
14	**1b** (Cl, Me, Ph)	**2a** (Bn, Ph)	**3aa**	24	61
15	**1c** (Br, Me, 4-$MeOC_6H_4$)	**2a** (Bn, Ph)	**3ca**	24	57
16	**1d** (Br, Me, 4-MeC_6H_4)	**2a** (Bn, Ph)	**3da**	24	71
17	**1e** (Br, Me, 4-BrC_6H_4)	**2a** (Bn, Ph)	**3ea**	24	80
18	**1f** (Br, Me, 4-ClC_6H_4)	**2a** (Bn, Ph)	**3fa**	24	86
19	**1g** (Br, Me, 4-FC_6H_4)	**2a** (Bn, Ph)	**3ga**	24	74
20	**1h** (Br, Me, 3-ClC_6H_4)	**2a** (Bn, Ph)	**3ha**	24	80
21	**1i** (Br, Me, 4-$NO_2C_6H_4$)	**2a** (Bn, Ph)	**3ia**	30	71
22	**1j** (Br, Me, *t*-Bu)	**2a** (Bn, Ph)	**3ja**	36	21
23	**1k** (Cl, Ph, Ph)	**2a** (Bn, Ph)	**3ka**	36	34
24	**1l** (Cl, MeO, Ph)	**2a** (Bn, Ph)	**3la**	30	59
25	**1m** (Br,MeO, CO_2Et)	**2a** (Bn, Ph)	**3ma**	30	70
26	**1n** 	**2a** (Bn, Ph)	**3na**	30	64
27	**1f** (Br, Me, 4-Cl C_6H_4)	**2b** (Bn, 4-$MeOC_6H_4$)	**3fb**	30	81
28	**1f** (Br, Me, 4-ClC_6H_4)	**2f** (Bn, 4-BrC_6H_4)	**3ff**	24	71
29	**1h** (Br, Me, 3-ClC_6H_4)	**2f** (Bn, 4-BrC_6H_4)	**3hf**	24	81
30	**1d** (Br, Me, 4-MeC_6H_4)	**2f** (Bn, 4-BrC_6H_4)	**3df**	24	73

[a] Unless otherwise noted, reactions were carried out with **1** (0.2 mmol), **2** (0.3 mmol), Na_2CO_3 (0.4 mmol) in toluene (1.0 mL) at room temperature. [b] Isolated yield.

imines **1d**, **1f** and **1h**, and the chemical yield of the [4 + 2] cycloaddition changed from 71–83%. Of course, the α-halogeno hydrazones **1f** and **1d**, where R^2 group individually has an electron-withdrawing or -donating group attached to the phenyl moiety, did not behaved quite differently in the [4 + 2] cycloaddition with **2f**, and furnished products **3ff** and **3df** in the similar chemical yields (entries 28 *vs.* 30).

Moreover, the chemical structure of **3aa** was firmly confirmed by single crystal X-ray analysis as depicted in Fig. 1.[13] The conformational analysis showed that the 2,3,4,5-tetrahydro-1,2,4-triazine ring of **3aa** adopts a highly twisted conformation. By virtue of the non-planar structure of the 2,3,4,5-tetrahydro-1,2,4-triazine ring of **3aa**, as a result, the two protons at C-5 become chemically non-equivalent: one proton occupies the pseudo-oxial position; the other one resides in the pseudo-equatorial position. This fact was clearly identified by the ^1H NMR performance of the two protons at C-5: one proton resonates at 3.48 ppm; the other one signals at 3.55 ppm (see details in ESI†). These observations proved that the inversion barrier of

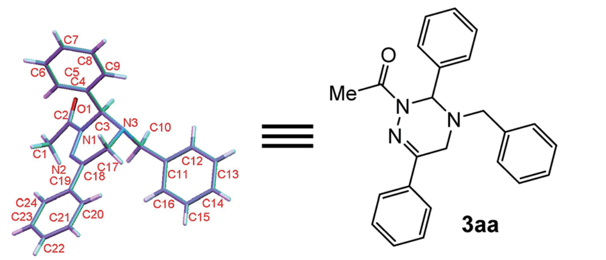


Fig. 1 X-ray single crystal structure of **3aa** (with thermal ellipsoid shown at the 50% probability level).

2,3,4,5-tetrahydro-1,2,4-triazine ring is big enough at room temperature, and as a consequence, the two protons exchange pretty slowly at ^{1}H NMR timescale. Meanwhile, we proposed the reaction mechanism for the formation of **3aa** (Scheme 2). In the presence of Na_2CO_3, the elimination reaction of **1a** takes place to give 1,2-diaza-1,3-diene **4**. Then, two possible transition states **TS1** and **TS2** will be produced for the [4 + 2] cycloaddition between **4** and **2a**. With the aid of the molecular model, it was found that in **TS2** phenyl group at C-6 sterically repulse benzyl group at N-4 severely; whereas, this strong destabilizing interaction does not exist in **TS1** at all. Therefore, the transition state **TS1** is more stable than the transition state **TS2**, and mainly accounts for the formation of the desired cycloadduct **3aa**.

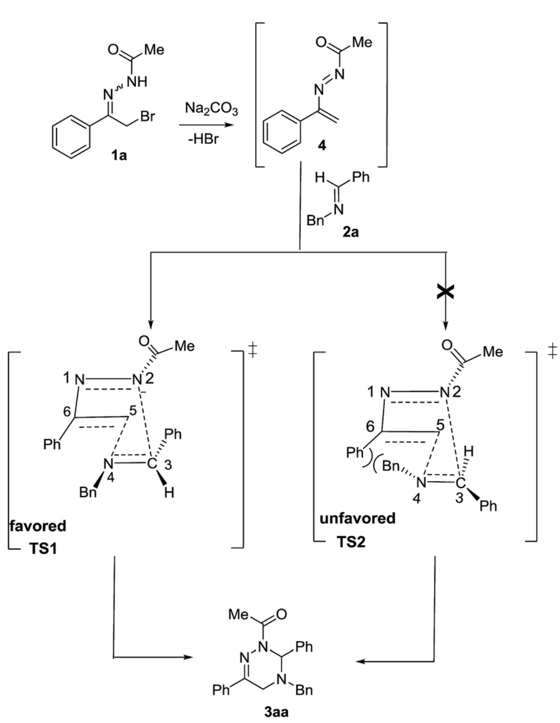
3. Conclusions

In conclusion, the [4 + 2] cycloaddition of α-halogeno hydrazones with imines underwent efficiently, and provided the easy access to the novel potentially bioactive 2,3,4,5-tetrahydro-1,2,4-triazines in the reasonable chemical yields. Furthermore, the exploration of other novel cycloadditions of α-halogeno hydrazones with various 1,3-, 1,4- and 1,5-dipoles is ongoing in our laboratory, and will be reported in due course.

4. Experimental section

4.1 General information

Proton (^{1}H) and carbon (^{13}C) NMR spectra were recorded on 400 MHz instrument (400 MHz for ^{1}H NMR, 100 MHz for ^{13}C NMR) and calibrated using tetramethylsilane (TMS) as internal reference. High resolution mass spectra (HRMS) were recorded



Scheme 2 Proposed mechanism for the formation of 3aa.

under electrospray ionization (ESI) conditions. Flash column chromatography was performed on silica gel (0.035–0.070 mm) using compressed air. Thin layer chromatography (TLC) was carried out on 0.25 mm SDS silica gel coated glass plates (60F254). Eluted plates were visualized using a 254 nm UV lamp. Unless otherwise indicated, all reagents were commercially available and used without further purification. All solvents were distilled from the appropriate drying agents immediately before using. α-Chloro- or α-bromo hydrazones (**1a–1n**) were prepared according to literature procedures.[3c,4,7b] Imines (**2a–2m**) were synthesized according to known procedures.[14]

4.2 Procedure for the synthesis of products 3

Na_2CO_3 (2.0 equiv., 0.4 mmol) was added to a solution of α-chloro- or α-bromo hydrazone **1** (1.0 equiv., 0.2 mmol) and imine **2** (1.5 equiv., 0.3 mmol) in toluene (1.0 mL). The mixture was monitored by TLC plate and stirred for 24–36 h at room temperature. The crude products were purified by flash column chromatography on silica gel using EtOAc–petroleum as eluent to give products **3** (21–88% yield).

1-(4-Benzyl-3,6-diphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)-ethanone (3aa). White solid, yield: 55.6 mg, 75%; mp = 164.0–165.2 °C ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66–7.64 (m, 2H), 7.45 (d, *J* = 7.2 Hz, 2H), 7.42–7.38 (m, 5H), 7.36–7.29 (m, 6H), 6.45 (s, 1H), 3.93 (d, *J* = 13.2 Hz, 1H), 3.77 (d, *J* = 13.2 Hz, 1H), 3.58–3.46 (m, 2H), 2.66 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.6, 145.4, 137.6, 137.5, 135.8, 129.7, 129.1, 128.8, 128.7, 128.6, 128.1, 127.8, 126.4, 125.0, 69.6, 58.7, 43.0, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{24}N_3O$ [M + H]$^+$: 370.19139, found 370.19046.

1-(4-Benzyl-3-(4-methoxyphenyl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ab). Oil, yield: 68.1 mg, 85%; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65–7.63 (m, 2H), 7.43 (d, *J* = 7.2 Hz, 2H), 7.40–7.37 (m, 5H), 7.34–7.31 (m, 1H), 7.21 (d, *J* = 8.4 Hz, 2H), 6.87 (d, *J* = 8.8 Hz, 2H), 6.39 (s, 1H), 3.90 (d, *J* = 13.2 Hz, 1H), 3.79 (s, 3H), 3.73 (d, *J* = 13.2 Hz, 1H), 3.55–3.46 (m, 2H), 2.63 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 159.5, 145.4, 137.7, 135.8, 129.7, 129.6, 129.0, 128.7, 128.6, 127.8, 127.6, 125.0, 114.1, 69.3, 58.5, 55.3, 42.9, 20.9 ppm; HRMS (ESI) calculated for $C_{25}H_{26}N_3O_2$ [M + H]$^+$: 400.20195, found 400.20111.

1-(4-Benzyl-3-(4-nitrophenyl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ac). Light yellow solid, yield: 55.5 mg, 67%; mp = 143.4–144.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.21 (d, *J* = 8.8 Hz, 2H), 7.64–7.62 (m, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 7.42–7.36 (m, 8H), 6.45 (s, 1H), 3.92 (d, *J* = 13.2 Hz, 1H), 3.80 (d, *J* = 12.8 Hz, 1H), 3.64–3.39 (m, 2H), 2.66 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.7, 147.9, 145.7, 144.9, 136.9, 135.2, 130.1, 129.1, 128.8, 128.7, 128.1, 127.7, 124.9, 124.0, 68.6, 58.9, 43.2, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}N_4O_3$ [M + H]$^+$: 415.17647, found 415.17526.

1-(4-Benzyl-3-(3-nitrophenyl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ad). Light yellow solid, yield: 51.4 mg, 62%; mp = 129.4–131.1 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.20–8.16 (m, 2H), 7.65–7.61 (m, 3H), 7.53 (t, *J* = 8.0 Hz, 1H), 7.45–7.43 (m, 3H), 7.41–7.36 (m, 5H), 6.46 (s, 1H), 3.95–3.79 (m, 2H), 3.65–3.41 (m, 2H), 2.68 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.8, 148.9, 145.7, 140.1, 136.9, 135.3, 132.7, 130.0, 129.9, 129.2, 128.8, 128.7, 128.1, 125.0, 123.3, 121.9, 68.4, 58.8, 43.0, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}N_4O_3$ [M + H]$^+$: 415.17647, found 415.17505.

1-(4-Benzyl-3-(2-nitrophenyl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ae). White solid, yield: 62.5 mg, 75%; mp = 153.3–154.5 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.88–7.86 (m, 1H), 7.56–7.54 (m, 2H), 7.51–7.45 (m, 2H), 7.40–7.31 (m, 6H), 7.27–7.24 (m, 3H), 7.05–7.03 (m, 1H), 4.07 (d, J = 12.8 Hz, 1H), 3.52 (d, J = 12.8 Hz, 1H), 3.43–2.91 (m, 2H), 2.66 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.6, 149.2, 145.3, 137.0, 135.3, 132.3, 131.7, 130.0, 129.4, 129.2, 128.7, 128.6, 127.9, 127.2, 125.5, 125.0, 68.1, 59.0, 40.4, 20.9 ppm; HRMS (ESI) calculated for $C_{24}H_{23}N_4O_3$ [M + H]$^+$: 415.17647, found 415.17542.

1-(4-Benzyl-3-(4-bromophenyl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3af). Oil, yield: 78.6 mg, 88%; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.65–7.63 (m, 2H), 7.48 (d, J = 8.4 Hz, 2H), 7.44–7.38 (m, 7H), 7.36–7.33 (m, 1H), 7.19 (d, J = 8.0 Hz, 2H), 6.38 (s, 1H), 3.92–3.74 (m, 2H), 3.59–3.44 (m, 2H), 2.65 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.6, 145.5, 137.4, 136.7, 135.6, 131.9, 129.9, 129.1, 128.7, 128.7, 128.3, 127.9, 125.0, 122.2, 68.9, 58.7, 43.0, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}BrN_3O$ [M + H]$^+$: 448.10190, found 448.10135.

1-(4-Benzyl-3-(naphthalen-2-yl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ag). White solid, yield: 55.2 mg, 66%; mp = 52.3–53.6 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.87 (d, J = 8.4 Hz, 1H), 7.85–7.80 (m, 2H), 7.65–7.63 (m, 2H), 7.59–7.56 (m, 2H), 7.50–7.46 (m, 4H), 7.45–7.41 (m, 2H), 7.39–7.34 (m, 4H), 6.60 (s, 1H), 4.00–3.80 (m, 2H), 3.59–3.47 (m, 2H), 2.73 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.6, 145.6, 137.6, 135.8, 134.9, 133.3, 133.2, 129.7, 129.2, 128.9, 128.7, 128.6, 128.3, 127.9, 127.6, 126.2, 126.2, 125.2, 125.0, 124.6, 69.7, 58.8, 43.2, 21.0 ppm; HRMS (ESI) calculated for $C_{28}H_{26}N_3O$ [M + H]$^+$: 420.20704, found 420.20602.

1-(4-Benzyl-3-(furan-2-yl)-6-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ah). White solid, yield: 57.3 mg, 80%; mp = 91.3–92.7 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.71–7.68 (m, 2H), 7.43–7.41 (m, 6H), 7.39–7.34 (m, 3H), 6.46 (s, 1H), 6.34–6.33 (m, 1H), 6.26 (d, J = 3.2 Hz, 1H), 3.87–3.79 (m, 2H), 3.68 (s, 2H), 2.56 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 171.9, 150.2, 145.0, 142.9, 137.0, 135.6, 129.8, 129.0, 128.7, 128.6, 127.8, 125.0, 110.3, 108.6, 64.0, 58.2, 44.0, 20.9 ppm; HRMS (ESI) calculated for $C_{22}H_{22}N_3O_2$ [M + H]$^+$: 360.17065, found 360.16971.

1-(4-(4-Methoxybenzyl)-3,6-diphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ai). White solid, yield: 23.2 mg, 29%; mp = 126.2–127.9 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.66–7.64 (m, 2H), 7.40–7.38 (m, 3H), 7.36–7.32 (m, 4H), 7.29–7.28 (m, 3H), 6.93 (d, J = 8.8 Hz, 2H), 6.42 (s, 1H), 3.85–3.82 (m, 4H), 3.70 (d, J = 12.8 Hz, 1H), 3.57–3.44 (m, 2H), 2.65 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.6, 159.3, 145.4, 137.6, 135.8, 130.3, 129.7, 129.6, 128.7, 128.6, 128.1, 126.4, 125.0, 114.1, 69.2, 58.0, 55.3, 42.9, 20.8 ppm; HRMS (ESI) calculated for $C_{25}H_{26}N_3O_2$ [M + H]$^+$: 400.20195, found 400.20111.

1-(4-(4-Fluorobenzyl)-3,6-diphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3aj). White solid, yield: 59.3 mg, 77%; mp = 132.1–133.7 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.66–7.64 (m, 2H), 7.43–7.38 (m, 5H), 7.35 (d, J = 7.2 Hz, 2H), 7.29 (d, J = 8.4 Hz, 3H), 7.11–7.07 (m, 2H), 6.42 (s, 1H), 3.89–3.72 (m, 2H), 3.56–3.46 (m, 2H), 2.66 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.6, 163.7, 161.2, 145.3, 137.4, 135.7, 133.3, 133.3, 130.7, 130.6, 129.8, 128.8, 128.6, 128.2, 126.4, 124.9, 115.6, 115.4, 69.3, 57.9, 43.1, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}FN_3O$ [M + H]$^+$: 388.18197, found 388.18085.

1-(4-(4-Chlorobenzyl)-3,6-diphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ak). White solid, yield: 62.2 mg, 77%; mp = 175.7–176.4 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.65–7.63 (m, 2H), 7.40–7.37 (m, 7H), 7.34 (d, J = 7.2 Hz, 2H), 7.31–7.27 (m, 3H), 6.41 (s, 1H), 3.89–3.71 (m, 2H), 3.50 (s, 2H), 2.64 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.5, 145.3, 137.3, 136.1, 135.7, 133.6, 130.4, 129.8, 128.9, 128.8, 128.6, 128.2, 126.4, 124.9, 69.4, 57.9, 43.1, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}ClN_3O$ [M + H]$^+$: 404.15242, found 404.15152.

1-(4-Methyl-3,6-diphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)-ethan-1-one (3al). White solid, yield: 44.0 mg, 75%; mp = 92.7–93.2 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.69–7.67 (m, 2H), 7.40 (t, J = 3.2 Hz, 3H), 7.37–7.33 (m, 2H), 7.31–7.27 (m, 3H), 6.35 (s, 1H), 3.55–3.40 (m, 2H), 2.61 (s, 3H), 2.60 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.7, 145.0, 137.3, 135.9, 129.7, 128.7, 128.6, 128.2, 126.4, 124.9, 71.3, 45.1, 42.7, 20.7 ppm; HRMS (ESI) calculated for $C_{18}H_{20}N_3O$ [M + H]$^+$: 294.16009, found 294.15924.

1-(3,4,6-Triphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3am). White solid, yield: 23.4 mg, 33%; mp = 131.1–132.7 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.74–7.71 (m, 2H), 7.42 (t, J = 3.2 Hz, 3H), 7.37–7.34 (m, 5H), 7.32–7.30 (m, 3H), 7.10 (d, J = 8.0 Hz, 2H), 7.02–6.99 (m, 1H), 4.42–3.96 (m, 2H), 2.58 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 171.8, 148.8, 146.1, 136.6, 135.1, 129.9, 129.7, 129.0, 128.7, 128.6, 128.4, 128.2, 126.2, 125.0, 121.7, 117.9, 67.6, 43.5, 32.6, 20.8 ppm; HRMS (ESI) calculated for $C_{23}H_{22}N_3O$ [M + H]$^+$: 356.17574, found 356.17426.

1-(4-Benzyl-6-(4-methoxyphenyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ca). Oil, yield: 45.2 mg, 57%; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.59 (d, J = 8.8 Hz, 2H), 7.44 (d, J = 6.8 Hz, 2H), 7.41–7.38 (m, 2H), 7.35–7.30 (m, 6H), 6.90 (d, J = 8.8 Hz, 2H), 6.44 (s, 1H), 3.92 (d, J = 12.8 Hz, 1H), 3.84 (s, 3H), 3.75 (d, J = 13.2 Hz, 1H), 3.54–3.42 (m, 2H), 2.64 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.4, 160.9, 145.2, 137.7, 137.6, 129.1, 128.7, 128.6, 128.5, 128.1, 127.8, 126.4, 126.4, 113.9, 69.5, 58.6, 55.4, 42.9, 20.8 ppm; HRMS (ESI) calculated for $C_{25}H_{26}N_3O_2$ [M + H]$^+$: 400.20195, found 400.20105.

1-(4-Benzyl-3-phenyl-6-(*p*-tolyl)-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3da). White solid, yield: 54.5 mg, 71%; mp = 93.3–94.7 °C; ^{1}H NMR (400 MHz, CDCl$_3$): δ 7.55 (d, J = 8.0 Hz, 2H), 7.45 (d, J = 6.8 Hz, 2H), 7.42–7.38 (m, 2H), 7.36–7.29 (m, 6H), 7.19 (d, J = 8.0 Hz, 2H), 6.45 (s, 1H), 3.94–3.75 (m, 2H), 3.56–3.44 (m, 2H), 2.65 (s, 3H), 2.39 (s, 3H) ppm; ^{13}C NMR (100 MHz, CDCl$_3$): δ 172.5, 145.5, 139.9, 137.7, 137.6, 133.1, 129.3, 129.1, 128.7, 128.7, 128.1, 127.8, 126.4, 124.9, 69.5, 58.7, 43.0, 21.4, 20.9 ppm; HRMS (ESI) calculated for $C_{25}H_{26}N_3O$ [M + H]$^+$: 384.20704, found 384.20621.

1-(4-Benzyl-6-(4-bromophenyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ea). White solid, yield: 71.1 mg, 80%; mp = 159.4–160.8 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50 (s, 4H), 7.45–7.40 (m, 3H), 7.38–7.35 (m, 4H), 7.31–7.29 (m, 3H), 6.46 (s, 1H), 3.94–3.73 (m, 2H), 3.52–3.42 (m, 2H), 2.65 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 144.3, 137.4, 137.4, 134.6, 131.7, 129.1, 128.8, 128.7, 128.2, 127.9, 126.4, 126.4, 124.0, 69.6, 58.7, 42.8, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}BrN_3O$ [M + H]$^+$: 448.10190, found 448.10092.

1-(4-Benzyl-6-(4-chlorophenyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3fa). White solid, yield: 69.2 mg, 86%; mp = 138.5–139.9 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.57 (d, J = 8.4 Hz, 2H), 7.45–7.39 (m, 5H), 7.36–7.34 (m, 4H), 7.32–7.30 (m, 3H), 6.46 (s, 1H), 3.93 (d, J = 12.8 Hz, 1H), 3.75 (d, J = 13.2 Hz, 1H), 3.53–3.43 (m, 2H), 2.65 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 144.3, 137.4, 137.4, 135.7, 134.2, 129.1, 128.8, 128.7, 128.2, 127.9, 126.4, 126.2, 69.6, 58.7, 42.8, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}ClN_3O$ [M + H]$^+$: 404.15242, found 404.15161.

1-(4-Benzyl-6-(4-fluorophenyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ga). White solid, yield: 57.1 mg, 74%; mp = 121.9–123.6 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.64–7.60 (m, 2H), 7.45–7.43 (m, 2H), 7.40 (t, J = 7.6 Hz, 2H), 7.36–7.29 (m, 6H), 7.09–7.04 (m, 2H), 6.44 (s, 1H), 3.94–3.73 (m, 2H), 3.53–3.42 (m, 2H), 2.64 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 164.9, 162.4, 144.4, 137.5, 137.4, 132.0, 132.0, 129.1, 128.8, 128.7, 128.2, 127.8, 126.9, 126.8, 126.4, 115.7, 115.5, 69.5, 58.7, 42.9, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}FN_3O$ [M + H]$^+$: 388.18197, found 388.18100.

1-(4-Benzyl-6-(3-chlorophenyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ha). White solid, yield: 64.9 mg, 80%; mp = 126.2–127.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (s, 1H), 7.46–7.42 (m, 4H), 7.40–7.38 (m, 2H), 7.37–7.35 (m, 3H), 7.32–7.28 (m, 4H), 6.45 (s, 1H), 3.93–3.73 (m, 2H), 3.48 (s, 2H), 2.65 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.6, 144.1, 137.5, 137.4, 137.3, 134.8, 129.9, 129.6, 129.1, 128.8, 128.7, 128.2, 127.9, 126.4, 125.0, 123.1, 69.6, 58.7, 43.0, 20.9 ppm; HRMS (ESI) calculated for $C_{24}H_{23}ClN_3O$ [M + H]$^+$: 404.15242, found 404.15158.

1-(4-Benzyl-6-(4-nitrophenyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ia). Light yellow solid, yield: 58.7 mg, 71%; mp = 116.2–117.5 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.22 (d, J = 8.8 Hz, 2H), 7.77 (d, J = 8.8 Hz, 2H), 7.43–7.39 (m, 4H), 7.37–7.33 (m, 3H), 7.31–7.27 (m, 3H), 6.46 (s, 1H), 3.94–3.73 (m, 2H), 3.52 (s, 2H), 2.66 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.6, 148.1, 143.0, 141.4, 137.2, 137.1, 129.0, 128.9, 128.8, 128.4, 128.0, 126.3, 125.6, 123.9, 69.9, 58.7, 42.9, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{23}N_4O_3$ [M + H]$^+$: 415.17647, found 415.17514.

1-(4-Benzyl-6-(*tert*-butyl)-3-phenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ja). White solid, yield: 14.7 mg, 21%; mp = 63.1–63.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.44 (d, J = 7.2 Hz, 2H), 7.41–7.37 (m, 2H), 7.35–7.29 (m, 4H), 7.24 (d, J = 7.2 Hz, 2H), 6.30 (s, 1H), 3.85–3.56 (m, 2H), 3.04 (s, 2H), 2.51 (s, 3H), 1.08 (s, 9H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 156.2, 137.9, 137.8, 129.0, 128.6, 127.9, 127.7, 126.3, 69.4, 58.2, 41.0, 37.5, 27.5, 20.7 ppm; HRMS (ESI) calculated for $C_{22}H_{28}N_3O$ [M + H]$^+$: 350.22269, found 350.22183.

(4-Benzyl-3,6-diphenyl-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)-(phenyl)methanone (3ka). Light yellow solid, yield: 29.6 mg, 34%; mp = 134.0–135.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.01 (d, J = 6.8 Hz, 2H), 7.61–7.55 (m, 3H), 7.51–7.49 (m, 4H), 7.45–7.37 (m, 6H), 7.35–7.30 (m, 5H), 6.61 (s, 1H), 4.12–3.90 (m, 2H), 3.65–3.55 (m, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.3, 145.6, 137.5, 137.3, 135.6, 134.5, 130.8, 130.4, 129.7, 129.1, 128.9, 128.8, 128.6, 128.2, 127.9, 127.6, 126.5, 125.0, 70.4, 58.9, 43.3, 27.0 ppm; HRMS (ESI) calculated for $C_{29}H_{26}N_3O$ [M + H]$^+$: 432.20704, found 432.20627.

Methyl 4-benzyl-3,6-diphenyl-4,5-dihydro-1,2,4-triazine-2(3*H*)-carboxylate (3la). White solid, yield: 45.8 mg, 59%; mp = 55.7–56.4 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.66 (s, 2H), 7.48 (d, J = 6.8 Hz, 2H), 7.44–7.40 (m, 2H), 7.38–7.31 (m, 9H), 6.20 (s, 1H), 4.02–3.84 (m, 5H), 3.56–3.43 (m, 2H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.0, 146.8, 137.9, 137.6, 135.9, 129.6, 129.1, 128.8, 128.7, 128.5, 128.2, 127.8, 126.3, 125.2, 72.0, 58.6, 53.7, 43.1 ppm; HRMS (ESI) calculated for $C_{24}H_{24}N_3O_2$ [M + H]$^+$: 386.18630, found 386.18539.

6-Ethyl 2-methyl 4-benzyl-3-phenyl-4,5-dihydro-1,2,4-triazine-2,6(3*H*)-dicarboxylate (3ma). Oil, yield: 53.5 mg, 70%; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.41–7.39 (m, 4H), 7.37–7.32 (m, 4H), 7.25 (d, J = 7.2 Hz, 2H), 6.07 (s, 1H), 4.34–4.29 (m, 2H), 3.96 (s, 3H), 3.82–3.73 (m, 2H), 3.56–3.51 (m, 1H), 3.26 (d, J = 19.2 Hz, 1H), 1.39–1.35 (m, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 163.0, 154.2, 140.2, 137.2, 137.0, 129.0, 128.9, 128.7, 128.5, 127.9, 126.1, 72.3, 62.0, 58.3, 54.3, 42.6, 14.1 ppm; HRMS (ESI) calculated for $C_{21}H_{24}N_3O_4$ [M + H]$^+$: 382.17613, found 382.17499.

4-Benzyl-3,6-diphenyl-2-tosyl-2,3,4,5-tetrahydro-1,2,4-triazine (3na). White solid, yield: 61.3 mg, 64%; mp = 110.5–111.3 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.94 (d, J = 8.4 Hz, 2H), 7.61–7.58 (m, 2H), 7.42–7.39 (m, 1H), 7.38–7.36 (m, 9H), 7.34–7.31 (m, 5H), 6.12 (s, 1H), 3.72 (d, J = 13.6 Hz, 1H), 3.50–3.43 (m, 2H), 3.35 (d, J = 18.4 Hz, 1H), 2.49 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 145.2, 144.0, 138.5, 137.3, 135.7, 129.5, 129.4, 129.0, 128.6, 128.5, 128.4, 128.3, 127.8, 126.9, 124.9, 74.4, 58.4, 42.1, 27.0, 21.7 ppm; HRMS (ESI) calculated for $C_{29}H_{28}N_3O_2S$ [M + H]$^+$: 482.18967, found 482.18881.

1-(4-Benzyl-6-(4-chlorophenyl)-3-(4-methoxyphenyl)-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3fb). Oil, yield: 70.0 mg, 81%; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.56 (d, J = 8.8 Hz, 2H), 7.43–7.37 (m, 4H), 7.35–7.33 (m, 3H), 7.21 (d, J = 8.4 Hz, 2H), 6.88 (d, J = 8.8 Hz, 2H), 6.39 (s, 1H), 3.90 (d, J = 13.2 Hz, 1H), 3.79 (s, 3H), 3.71 (d, J = 12.8 Hz, 1H), 3.46 (s, 2H), 2.63 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.4, 159.5, 144.2, 137.5, 135.6, 134.2, 129.4, 129.0, 128.8, 128.7, 127.8, 127.6, 126.2, 114.2, 69.4, 58.5, 55.3, 42.7, 20.8 ppm; HRMS (ESI) calculated for $C_{25}H_{25}ClN_3O_2$ [M + H]$^+$: 434.16298, found 434.16229.

1-(4-Benzyl-3-(4-bromophenyl)-6-(4-chlorophenyl)-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3ff). White solid, yield: 68.3 mg, 71%; mp = 153.2–154.0 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.55 (d, J = 8.4 Hz, 2H), 7.47 (d, J = 8.4 Hz, 2H), 7.40–7.39 (m, 4H), 7.36–7.34 (m, 3H), 7.17 (d, J = 8.4 Hz, 2H), 6.37 (s, 1H), 3.91–3.71 (m, 2H), 3.52–3.39 (m, 2H), 2.62 (s, 3H) ppm;

^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 144.4, 137.2, 136.6, 135.8, 134.0, 132.0, 129.0, 128.8, 128.7, 128.2, 128.0, 126.2, 122.2, 69.0, 58.7, 42.8, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{22}BrClN_3O$ $[M + H]^+$: 482.06293, found 482.06226.

1-(4-Benzyl-3-(4-bromophenyl)-6-(3-chlorophenyl)-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3hf). Oil, yield: 77.8 mg, 81%; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.65 (s, 1H), 7.49 (s, 1H), 7.47–7.43 (m, 2H), 7.41–7.40 (m, 4H), 7.38–7.36 (m, 2H), 7.31 (d, J = 8.0 Hz, 1H), 7.16 (d, J = 8.4 Hz, 2H), 6.37 (s, 1H), 3.90–3.72 (m, 2H), 3.53–3.41 (m, 2H), 2.64 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 144.1, 137.3, 137.1, 136.5, 134.9, 132.0, 129.9, 129.7, 129.0, 128.8, 128.2, 128.0, 125.0, 123.0, 122.3, 69.0, 58.7, 43.0, 20.8 ppm; HRMS (ESI) calculated for $C_{24}H_{22}BrClN_3O$ $[M + H]^+$: 482.06293, found 482.06238.

1-(4-Benzyl-3-(4-bromophenyl)-6-(*p*-tolyl)-4,5-dihydro-1,2,4-triazin-2(3*H*)-yl)ethan-1-one (3df). White solid, yield: 67.5 mg, 73%; mp = 133.9–134.7 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.54 (d, J = 8.0 Hz, 2H), 7.48 (d, J = 8.4 Hz, 2H), 7.44–7.33 (m, 5H), 7.21–7.19 (m, 4H), 6.38 (s, 1H), 3.92–3.74 (m, 2H), 3.57–3.42 (m, 2H), 2.65 (s, 3H), 2.40 (s, 3H) ppm; ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 145.6, 140.1, 137.4, 136.8, 132.8, 131.9, 129.3, 129.1, 128.7, 128.3, 127.9, 124.9, 122.1, 68.9, 58.6, 42.9, 21.4, 20.8 ppm; HRMS (ESI) calculated for $C_{25}H_{25}BrN_3O$ $[M + H]^+$: 462.11755, found 462.11670.

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