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H-Y ZEOLITE: A REUSABLE CATALYST FOR ONE-POT ULTRASOUND-ASSISTED SYNTHESIS OF BICYCLIC Δ^2-1,2,3-TRIAZOLINES

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ABSTRACT: The request for greenly efficient catalytic technology continues to intensify in current environmentally catalysis methods. In this decade, catalysis science is working towards a solution through the production of efficient heterogeneous catalysts for environmental applications. In this paper, we report the one-pot synthesis of bicyclic Δ^2-1,2,3-triazolines assisted by ultrasound using H-Y zeolite as a catalyst. The catalytic activity of H-Y proved to be very efficient for the 1,3-dipolar cycloaddition reaction of organic azides with cyclic enamines formed *in-situ* and high yields of bicyclic Δ^2-1,2,3-triazolines were obtained in a short time. The reuse of zeolite H-Y in several cycles showed that this catalyst was stable during four consecutive reuse tests.

KEYWORDS: One-pot Synthesis, Ultrasound, Zeolite H-Y, Heterogeneous Acid Catalysis, Bicyclic Δ^2-1,2,3-Triazolines

INTRODUCTION:

An important part of heterocyclic chemistry contains triazolic ring and its derivatives. Triazoles and Triazolines have received considerable attention for their synthetic and biological value. They have been recognized for their antitubercular[i], anticonvulsant[ii], antioxidant[iii], antidiabetic[iv], antifungal[v], anti-inflammatory[vi], and anticancer[vii] activities for over two decades. Moreover, 1,3-dipolar cycloaddition reactions are one of the most versatile and efficient routes to a large variety of heterocyclic compounds[viii]. Many synthetic approaches have been reported for preparing triazoles derivatives, in particular, Huisgen 1,3-dipolar cycloaddition by the reaction of azides with monosubstituted acetylenes which requires harsh conditions and poor regioselectivity[ix], and the copper-catalyzed azide-alkyne (CuAAC) pioneering work of Sharpless which has increased the reaction rate and results in regioselectivity[x]. The synthesis of 1,2,3-triazolines is also rich chemistry based on the high reactivity and regioselectivity of the reaction between organic azides and enamines[xi]. Three main routes can be used to synthesize 1,2,3-triazolines, the first concerns the isomerization of arylazoaziridines[xii],

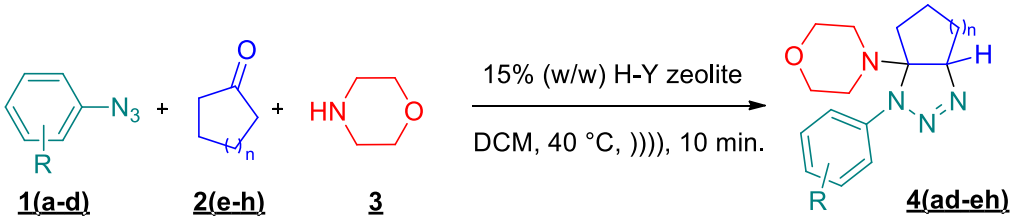
secondly, 1,3-dipolar cycloaddition diazoalkenes to Schiff bases[xiii] and the third synthetic route is the 1,3-dipolar cycloaddition of azides to ethylenic compounds[xiv,xv] which we chose for our study. These last years, many synthetic approaches for preparing 1,2,3-triazolines and its derivatives have been reported[xvi-xxiii], some reactions have been developed using catalysts such as a silver in the three-component route to trifluoromethylated 1,2,3-triazoline[xxiv], or iridium in the click chemistry with strain-loadable alkenes[xxv].

The challenges of this century have focused on the development of science and technology in the context of sustainable and environmentally against negligent and uncontrolled production. Consequently, in the field of environmental concern, more green catalysts recyclable have been developed and used in 1,3-dipolar cycloaddition in a conventional method[xxvi,xxvii]. Furthermore, Ultrasound-assisted organic synthesis is a powerful technique for green and sustainable synthetic processes, which is used to accelerate organic reaction. The attractive features of the ultrasound approach are improved reactions rate, formation of pure product in high yields, and easier manipulation[xxviii]. A growing number of studies have discussed the use of ultrasound technology in the synthesis of triazoles using Cu(I) as a catalyst[xxix-xxxi], Cu(II)-clay[xxxii], iron-copper[xxxiii], or nanoparticles[xxxiv]. But till now, no 'one-pot' synthesis of bicyclic Δ^2-1,2,3-triazolines assisted by ultrasound and catalyzed by porous material has been reported yet.

In continuation of our previous work on going toward usage of non-conventional methods in the synthesis of 1,2,3-triazolines[xvii,xviii], we present in this paper a one-pot synthesis of bicyclic Δ^2-1,2,3-triazolines from cyclic ketones, morpholine and some arylazides catalyzed by zeolite H-Y which proved a performance as well as a recyclable and non-toxic heterogeneous acid catalyst in the rapid synthesis of cyclic enamines[xxxv], under ultrasonic irradiation for a very short time with high yields of isolated products **(Scheme 1)**.

EXPERIMENTAL:

GENERAL PROCEDURE FOR THE SYNTHESIS OF BICYCLIC Δ^2-1,2,3-TRIAZOLINES:



1(a-d) **2(e-h)** **3** **4(ad-eh)**

a = R = -H
b = R = 4-NO_2
c = R = 2-Cl,4-NO_2
d = R = 4-Br

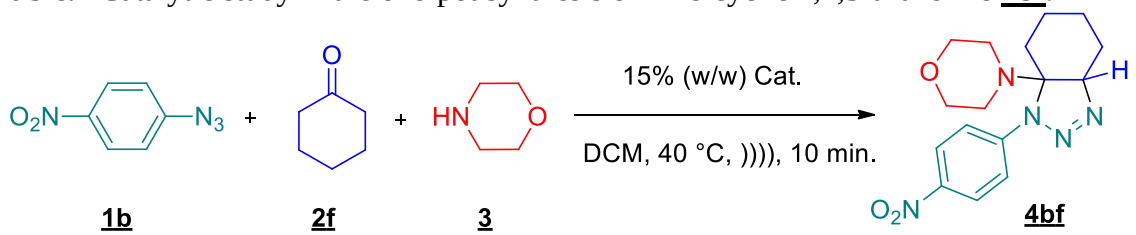
e = n = 1
f = n = 2
g = n = 3
h = n = 4

Scheme1. General route for the synthesis of bicyclic Δ^2-1,2,3-triazolines.

A mixture of morpholine **3** (1.3 mmol, 0.112 g), cyclic ketone **2(e-h)** (1.2 mmol), organic azide **1(a-d)** (1 mmol), zeolite H-Y (15% w/w) and 3 mL of DCM was treated under radiation by probe sonication with an amplitude of 80% using an ultrasound generator. The reaction mixture is carried out at 40 °C. After 10 minutes, the H-Y zeolite is filtered and washed with the DCM and then the reaction mixture is evaporated. When the product is liquid, it is purified on a silica column in a mixture Petroleum ether / Ethyl acetate. If the product is solid, it is washed with Et_2O in order to eliminate the starting products. The reaction leads to the expected bicyclic triazolines unless otherwise indicated.

RESULTS AND DISCUSSION:

Table.1 Catalytic study in the one-pot synthesis of Δ^2-bicyclic 1,2,3-triazoline **4bf**.



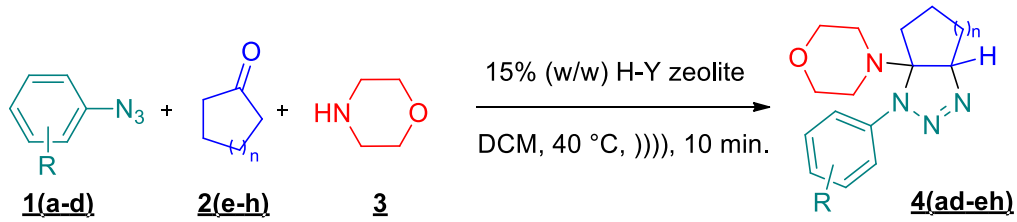
1b **2f** **3** **4bf**

Entry	Catalyst	Yield*
1	-	80%
2	Y zeolite	93%
3	**H-Y zeolite**	**98%**

Morpholine (1.3 mmol), Cycloalkanones (1.2 mmol), Arylazides (1 mmol), DCM (3 mL), H-Y 15% (w/w) (the H-Y zeolite was prepared according to a well-established procedure[xxxv]).

The one-pot synthesis of triazoline **4bf** from morpholine **3**, cyclohexanone **2f** and 4-nitrophenylazide **1b** assisted by ultrasound **(Table.1)** was carried out in ten minutes without catalyst (Entry 1) with a yield of 80%. The presence of zeolite Y which has an acidic character has improved the yield to 93% (Entry 2). Furthermore, the protonated zeolite Y with a more acidic character increased the yield to 98% in just 10 minutes (Entry 3).

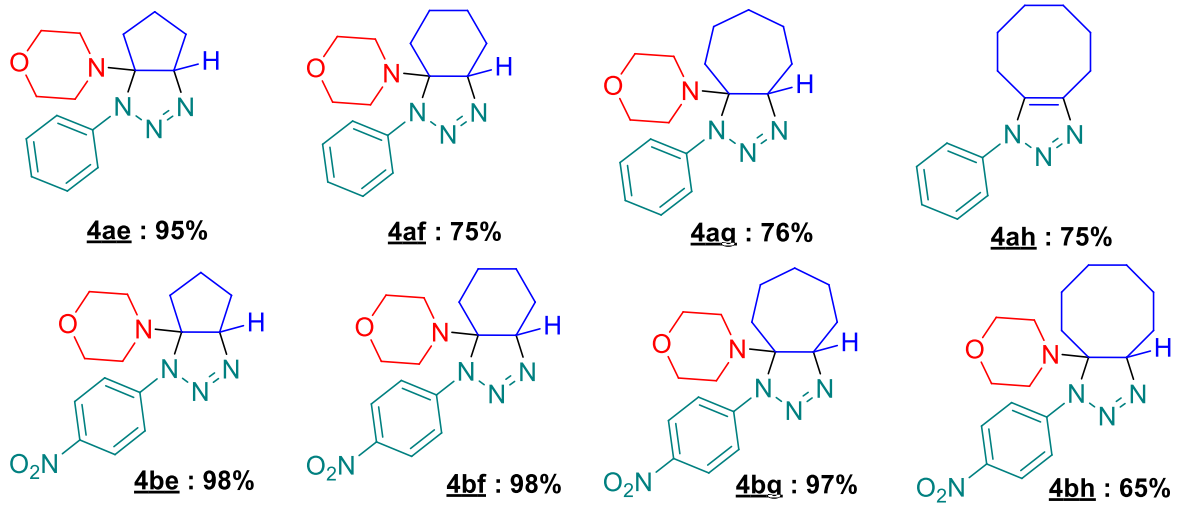
Table 2. One-pot synthesis of bicyclic Δ^2-1,2,3-triazolines from morpholine, cycloalkanones and arylazides.



1(a-d) **2(e-h)** **3** **4(ad-eh)**

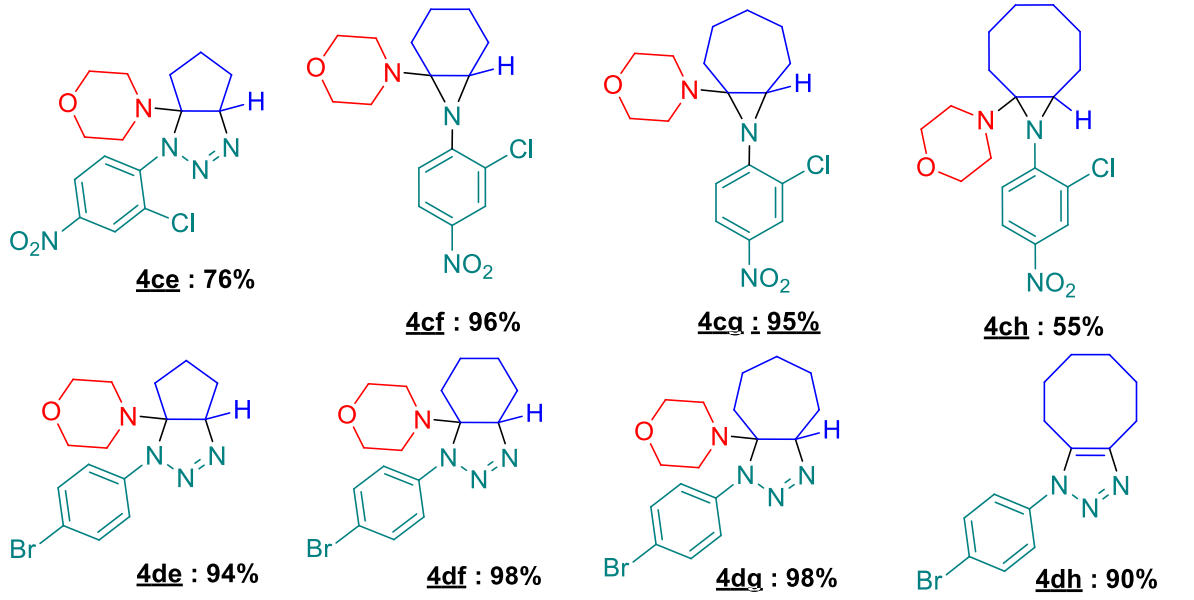
a = R = -H
b = R = 4-NO_2
c = R = 2-Cl,4-NO_2
d = R = 4-Br

e = n = 1
f = n = 2
g = n = 3
h = n = 4



4ae : 95% **4af** : 75% **4ag** : 76% **4ah** : 75%

4be : 98% **4bf** : 98% **4bg** : 97% **4bh** : 65%



Morpholine (1.3 mmol), Cycloalkanones (1.2 mmol), Arylazides (1 mmol), DCM (3 mL), H-Y 15% (w/w).

Table 2 shows the scope of the one-pot synthesis of some Δ^2-bicyclic 1,2,3-triazolines from morpholine **3**, cycloalkanones **2(e-h)** and arylazides **1(a-d)** using H-Y as a catalyst and assisted by ultrasounds in 10 minutes with good yields. Triazolines **4be**, **4bf**, **4df** and **4dg** were obtained with the best yield of 98% using *p*-bromophenylazide with enamines formed *in-situ* between morpholine/cyclohexanone and cycloheptanone, and also in the presence of *p*-nitrophenylazide with enamines formed *in-situ* between morpholine/cyclopentanone and cyclohexanone. Furthermore, we note an aromatization of triazolines **4ah** and **4dh** due to the departure of the morpholine group for enamine formed between morpholine and cyclooctanone in the presence of phenylazide and *p*-bromophenylazide. However, the use of 2-chloro-4-nitrophenylazide in the presence of enamines formed between cycloalkanone with 6, 7 and 8 chains, we note the formation of the corresponding aziridines **4cf**, **4cg** and **4ch** due to the degradation of triazoline[xiv].

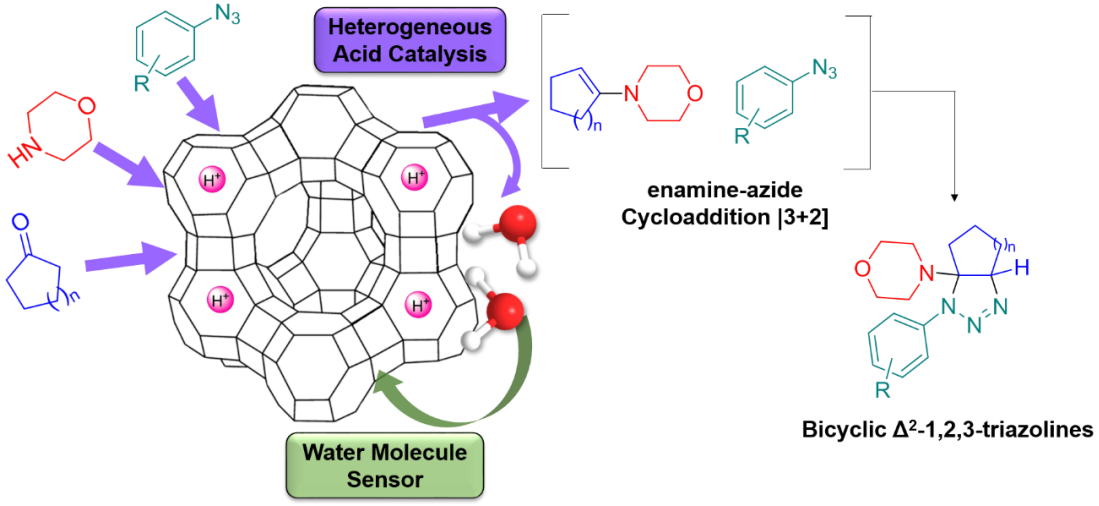


Figure. 1 Action of H-Y zeolite in the one-pot synthesis of Δ^2-1,2,3-triazolines.

The H-Y zeolite plays the role of acid catalyst and adsorbent in the synthesis of triazolines by multicomponent reaction. Indeed, cyclic enamine is easily and rapidly formed *in-situ*[xxxv] which subsequently react with organo-azide according to a concerted mechanism of 1,3-dipolar cycloaddition leading to the direct formation of the corresponding triazoline **(Figure. 1)**

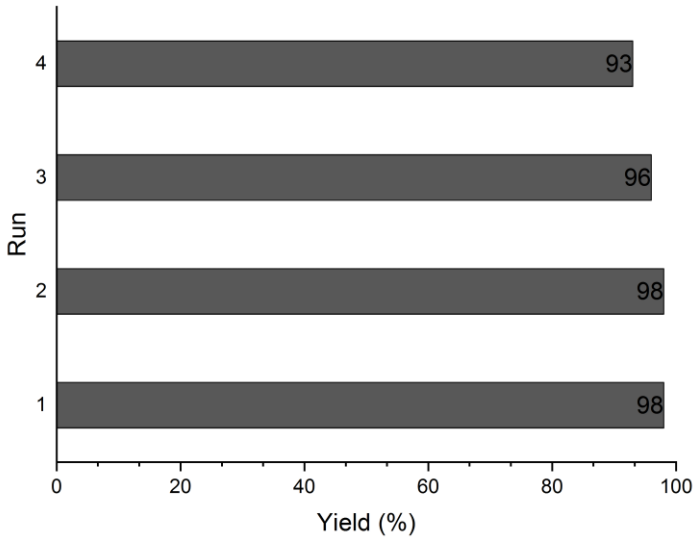


Figure. 2 Recycling of H-Y in the synthesis of triazoline **4bf**.

The recycling of the catalyst is shown in **Figure. 2**. H-Y zeolite can be reused four times in the one-pot synthesis of triazoline **4bf** under the same reaction conditions without a significant loss of catalytic activity. Between each run, there is a minor decline in yield. The catalyst is recovered by simple filtration, washed by DCM to remove all products and then dried before use for the next cycle.

CONCLUSION:

We have shown in this paper the catalytic effect of H-Y zeolite which proved a new performance as well as a recyclable and non-toxic heterogeneous acid catalyst in the synthesis of bicyclic Δ^2-1,2,3-triazolines by "one-pot reaction" assisted by ultrasound through a concerted 1,3-dipolar cycloaddition [azide-enamines formed *in-situ*] mechanism.

ACKNOWLEDGEMENT:

The authors are very grateful to Dr. Z. Cherifi for his help and "Direction Générale de la Recherche Scientifique et du Développement Technologique" DGRSDT for financial support.

ANALYTICAL DATA FOR COMPOUNDS:

Spectra of the final products were recorded on a Brüker Avance-300 spectrometer for NMR (300 MHz and 75 MHz for ^{1}H and ^{13}C respectively) in $CDCl_3$. Chemical shifts are reported in ppm, referenced to tetramethylsilane (TMS) as the external reference. Coupling constants (*J*) are reported in Hertz. Abbreviations to denote the multiplicity of a particular signal are s (singlet), d (doublet), dd (doublet of doublet), dt (doublet of triplet).

4-(3-phenyl-3,3a,4,5,6,6a-hexahydrocyclopenta[*d*][1,2,3]triazol-3a-yl)morpholine 4ae: Brown Solid; mp 98-99 °C; Yield 95%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm :1.20-1.37 (m, 1H), 1.58-1.69 (m, 1H), 1.88-1.97 (m, 1H), 2-2.16 (m, 2H), 2.19-2.29 (m, 1H), 2.44 (t, *J* = 4.5 Hz, 4H), 3.68 (t, *J* = 4.5 Hz, 4H), 4.79 (dd, *J* = 5.3 Hz ; *J* = 3.6 Hz, 1H), 7.07 (t, *J* = 7,3 Hz, 1H), 7.33 (t, *J* = 7.5 Hz, 2H), 7.63 (d, *J* = 7.8 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): 23.2, 32.3, 33.4, 46.4, 66.9, 78.0, 91.0, 116.7, 123.1, 129.0, 139.4; Anal. Calcd for $C_{15}H_{20}N_4O$ (%): C 66.15, H 7.40, N 20.57. Found C 66.12, H 7.60, N 20.97; MS (ESI) m/z (%): 273.171 $(M+H)^+$

4-(1-phenyl-3a,4,5,6,7,7a-hexahydro-1*H*-benzo[*d*][1,2,3]triazol-7a-yl)morpholine 4af: Orange oil, Yield 75%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.00-1.18 (m, 2H),1.42-1.56 (m,

2H), 1.70-1.74 (m, 1H), 1.85-1.89 (m, 1H), 2.01-2.06 (m, 2H), 2.41-2.50(m, 4H), 3.69 (t, 4H, *J* = 4.5 Hz), 4.63 (dd, 1H, *J* = 5.6, 3.2 Hz), 7.03 (d, 1H, *J* = 8.0 Hz), 7.14 (t, 1H, *J* = 7.6 Hz), 7.34 (t, 1H, J = 8 Hz), 7.36 (t, 1H, *J* = 8 Hz), 7.68 (d, 1H, *J* = 8.1 Hz); ^{13}C NMR (75 MHz, $CDCl_3$): 14.84, 16.76, 23.52, 24.98, 45.13, 66.99, 73.52, 80.98, 117.56, 119.01, 123.77, 129.06, 129.76, 140.14; Anal. Calcd for $C_{16}H_{22}N_4O$ (%): C 67.11, H 7.74, N 19.56. Found C 68.51, H 7.59, N 19.57.

4-(3-phenyl-3,3a,4,5,6,7,8,8a-octahydrocyclohepta[*d*][1,2,3]triazol-3a-yl)morpholine 4ag: Brown liquid; Yield 76%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 0.77-0.94 (m, 2H), 0.98-1.18 (m, 1H), 1.48-1.70 (m, 4H), 2.04-2.09 (m, 1H), 2.29-2.32 (m, 1H), 2.34-2.39 (m, 4H), 2.47-2.56 (m, 1H), 3.65 (t, *J* = 4.6 Hz, 4H), 4.62 (t, *J* = 3,9 Hz, 1H), 7.06 (td, *J* = 7.3 Hz ; *J* = 0.8 Hz, 1H), 7.69 (dd, *J* = 7.8 Hz ; *J* = 0.8 Hz, 2H), 7.30 (t, *J* = 7.8 Hz, 2H).^{13}C NMR (75 MHz, $CDCl_3$): 23.7, 26.9, 30.1, 30.7, 31.4, 44.9, 66.8, 77.2, 84.5, 117.2, 123.6, 128.9, 139.9; Anal. Calcd for $C_{17}H_{24}N_4O$ (%): C 67.97, H 8.05, N 18.65. Found C 68.41, H 8.32, N 18.61.

1-phenyl-4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazole 4ah: Yellow oil; Yield 75%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.48-1.63 (m, 4H), 1.68-1.83 (m, 4H), 2.71 (t, *J* = 6.4 Hz, 2H), 2.93 (t, *J* = 6,4 Hz, 2H), 7.36 (dd, *J* = 5.8 Hz ; *J* = 2,0 Hz, 2H), 7.46 (t, *J* = 6.6 Hz, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): 21.9, 24.3, 25.1, 25.4, 27.1, 28.0, 125.1, 126.5, 29.2, 133.8, 136.5, 144.9; Anal. Calcd for $C_{14}H_{17}N_3$ (%): C 73.98, H 7.54, N 18.49. Found C 71.29, H 7.74, N 17.29.

4-(3-(4-nitrophenyl)-3,3a,4,5,6,6a-hexahydrocyclopenta[*d*][1,2,3]triazol-3a-yl)morpholine 4be: Yellow solid; mp 173-175 °C; Yield 98%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.24-1.41 (m, 1H), 1.64-1.76 (m, 1H), 1.90-2.00 (m, 1H), 2.07-2.18 (m, 2H), 2.29-2.31 (m, 1H), 2.34-2.39 (m, 2H), 2.44-2.50 (m, 2H), 3.66-3.69 (m, 4H), 4.93 (dd, *J* = 5,1 Hz ; *J* = 3,7 Hz, 1H), 7.76 (d, *J* = 9.2 Hz, 2H), 8.21 (d, *J* = 9.2 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): 23.3, 32.2, 33.1, 46.3, 66.7, 79.2, 90.5, 115, 119.3, 125.3, 144.3; Anal. Calcd for $C_{15}H_{19}N_5O_3$ (%): C 56.77, H 6.03, N 22.07. Found C 56.75, H 6.13, N 22.04; MS (ESI) m/z (%): 356.2 $((M+K)^+$

4-(1-(4-nitrophenyl)-3a,4,5,6,7,7a-hexahydro-1*H*-benzo[*d*][1,2,3]triazol-7a-yl)morpholine 4bf: Yellow solid; mp 189-190 °C; Yield 98%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 0.97-1.15 (m, 2H),1.48-1.60 (m, 2H), 1.68-1.83 (m, 1H), 2.01-2.11 (m, 1H), 2.11-2.21 (m, 2H), 2.27-2.38 (m, 2H), 2.47 2.57 (m, 2H), 3.68 (t, 4H, *J* = 4.6 Hz), 4.77 (dd, 1H, *J* = 5.5, *J* = 2.7 Hz), 7.84 (d, 2H, *J* = 9.3 Hz), 8.22 (d, 2H, *J* = 9.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$): 14.42, 16.45, 22.00, 22.91, 45.02, 66.72, 74.89, 80.85, 115.53, 125.24, 142.84, 145.24. Anal. Calcd for $C_{16}H_{21}N_5O_3$ (%): C 57.99, H 6.39, N 21.13. Found C 57.83, H 6.60, N 21.72; MS (ESI) m/z (%): 332.1 $(M+H)^+$

4-(3-(4-nitrophenyl)-3,3a,4,5,6,7,8,8a-octahydrocyclohepta[*d*][1,2,3]triazol-3a-yl)morpholine 4bg: Red solid; mp 207 °C; Yield 97%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 0.69-0.93 (m, 2H), 1.03-1.16 (m, 1H), 1.54-1.71 (m, 4H), 2.08-2.17 (m, 1H), 2.23-2.30 (m, 2H), 2.38-2.42 (m, 2H), 2.45-2.50 (m, 1H), 2.58-2.67 (m, 1H), 3.67 (t, *J* = 4.4 Hz, 4H), 4.78 (t, *J* = 3.9 Hz, 1H), 7.85 (d, *J* = 9.4 Hz, 2H), 8.20 (d, *J* = 9.4 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): 23.7, 23.8, 29.4, 30.7, 31.0, 45.0, 66.7, 78.2, 84.3, 115.7, 125.3, 142.8, 145.2; Anal. Calcd for $C_{17}H_{23}N_5O_3$ (%): C 59.12, H 6.71, N 20.28. Found C 60.71, H 7.10, N 20.80.

4-(1-(4-nitrophenyl)-3a,4,5,6,7,8,9,9a-octahydro-1*H*-cycloocta[*d*][1,2,3]triazol-9a-yl)morpholine 4bh: Yellow solid; mp 139-141 °C; Yield 65%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 0.90-1.03 (m, 1H), 1.05-1.15 (m, 1H), 1.20-1.27 (m, 1H), 1.29-1.43 (m, 3H), 1.51-1.60 (m, 2H), 1.68-1.78 (m, 1H), 2.15-2.21 (m, 2H) , 2.29-2.42 (m, 4H), 2.61-2.72 (m, 1H), 3.60-3.70 (m, 4H), 4.71 (d, *J* = 8.0 Hz, 1H), 7.83 (d, *J* = 9.2 Hz, 2H), 8.19 (d, *J* = 9.2 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): 24.6, 24.5, 24.9, 25.4, 28.1, 29.5, 45.0, 66.7, 78.3, 82.2, 115.2, 125.3,

142.7, 146.3; Anal. Calcd for $C_{18}H_{25}N_5O_3$ (%): C 60.15, H 7.01, N 19.48. Found C 60.25, H 7.10, N 19.60.

4-(3-(2-chloro-4-nitrophenyl)-3,3a,4,5,6,6a-hexahydrocyclopenta[*d*][1,2,3]triazol-3a-yl)morpholine 4ce: Brown solid; mp 99-101 °C; Yield 76%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.42-1.57 (m, 1H), 1.63-1.73 (m, 1H), 1.74-1.82 (m, 1H), 1.95-2.15 (m, 2H), 2.20-2.30 (m, 1H), 2.47 (t, *J* = 4.7 Hz, 4H), 3.73 (t, *J* = 4.7 Hz, 4H), 4.82 (dd, *J* = 5.6 Hz ; *J* = 3.6 Hz, 1H), 7.76 (d, *J* = 9.1 Hz, 1H), 8.12 (dd, *J* = 6.5 Hz ; *J* = 2.5 Hz, 1H), 8.33 (d, *J* = 2.5 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): 23.8, 32.1, 32.8, 46.3, 66.7, 77.9, 92.9, 122.3, 122.6, 127.1, 128.7, 142, 144.4; Anal. Calcd for $C_{15}H_{18}ClN_5O_3$ (%): C 51.21 H 5.16, N 19.91. Found C 51.94, H 5.31, N 18.31.

4-(7-(2-chloro-4-nitrophenyl)-7-azabicyclo[4.1.0]heptan-1-yl)morpholine 4cf: Red solid; mp 85-87 °C; Yield 96%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.49-1.57 (m, 2H), 1.62-1.74 (m, 4H), 1.80-1.89 (m, 2H), 2.70-2,82 (m, 1H), 3.50 (t, *J* = 4,7 Hz, 2H), 3.74 (t, *J* = 4,8 Hz, 4H), 6.74 (d, *J* = 8.1 Hz 1H), 7.99 (dd, *J* = 6.3 Hz, *J* = 2.6 Hz, 1H), 8.23 (d, *J* = 2.6 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): 26, 30.4, 41.8, 46.5, 66.6, 66.8, 121.6, 123.1, 125.4, 125.6, 154.9, 161.4; Anal. Calcd for $C_{16}H_{20}ClN_3O_3$ (%): C 56.89, H 5.97, N 12.44. Found C 56.73, H 6.08, N 12.35; MS (ESI) m/z (%): 337.9 $(M+H)^+$

4-(8-(2-chloro-4-nitrophenyl)-8-azabicyclo[5.1.0]octan-1-yl)morpholine 4cg: Red solid; mp 89 °C; Yield 95%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.05-1.08 (m, 2H), 1.11-1.14 (m, 1H), 1.33-1,46 (m, 2H), 1.59-1.64 (m, 1H), 1.69-1.74 (m, 2H), 1.77-1.82 (m, 2H), 2.43 (td, *J* = 12.3 Hz ; *J* = 3.0 Hz, 1H), 3.51 (t, *J* = 4.7 Hz, 4H), 3.72 (t, *J* = 4.7 Hz, 4H), 6.73 (d, *J* = 8.6 Hz, 1H), 7.97 (dd, *J* = 6.3 Hz ; *J* = 2,4 Hz, 1H), 8.22 (d, *J* = 2.7 Hz,1H); ^{13}C NMR (75 MHz, $CDCl_3$): 25.6, 26.2, 29.9, 42.8, 46.6, 66.6, 77.2, 121.3, 122.9, 125.4, 141.1, 154.8, 161.1; Anal. Calcd for $C_{17}H_{22}ClN_3O_3$ (%): C 58.04, H 6.30, N 11.94. Found C 56.67, H 6.01, N 11.84; MS (ESI) m/z (%): 374.1 $(M+Na)^+$

4-(9-(2-chloro-4-nitrophenyl)-9-azabicyclo[6.1.0]nonan-1-yl)morpholine 4ch: Brown oil; Yield 55%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.24-1.32 (m, 1H), 1.36-1.43 (m, 4H), 1.55-1.59 (m, 1H), 1.60-1.72 (m, 4H), 1.78-1.98 (m, 2H), 2.45-2.59 (m, 1H), 3.53 (t, *J* = 4.3 Hz, 4H), 3.74 (t, *J* = 4.3 Hz, 4H), 6.74 (d, *J* = 8.7 Hz, 1H), 8.01 (dd, *J* = 6.6 Hz; *J* = 2.2 Hz, 1H), 8.25 (d, *J* = 2.3 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): 24.4, 24.6, 24.8, 25.4, 28,0, 29.8, 43.0, 46.5, 66.7, 77.1, 121.5, 122.9, 125.4, 141.2, 155.0, 161.3.

4-(3-(4-bromophenyl)-3,3a,4,5,6,6a-hexahydrocyclopenta[*d*][1,2,3]triazol-3a-yl)morpholine 4de: Brown solid, mp 104-106 °C; Yield 94%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.19-1.35 (m, 1H), 1.58-1.69 (m, 1H), 1.86-1.96 (m, 1H), 2-2.13 (m, 2H), 2.19-2.29 (m, 1H), 2.33-2.47 (m, 4H), 3.66 (t, *J* = 4,6 Hz, 4H), 4.80 (dd, *J* = 5,2 Hz ; *J* = 3.6 Hz, 1H), 7.41 (d, *J* = 9 Hz, 2H), 7.52 d, *J* = 9, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): 23.2, 32.1, 33.3, 46.3, 66.8, 78.1, 90.9, 115.7, 117.9, 132, 138.3; MS (ESI) m/z (%): 375.5 $(M+Na)^+$

4-(1-(4-bromophenyl)-3a,4,5,6,7,7a-hexahydro-1*H*-benzo[*d*][1,2,3]triazol-7a-yl)morpholine 4df: White solid; mp 140-144 °C; Yield 98%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 0.99-1.07 (m, 2H) ,1.42- 1.45 (m, 2H), 1.64-1.71 (m, 1H), 1.91 1.99 (m, 1H), 1.99-2.04 (m, 2H), 2.30-2.35(m, 2H), 2.40-2.45 (m, 2H), 3.63 (t, 4H, *J* = 4.6 Hz), 4.60 (dd, 1H, J = 5.4, *J* = 2.9 Hz), 7.40 (d, 2H, *J* = 7.0 Hz), 7.55 (d, 2H, *J* = 7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$): 14.62, 16.55, 21.82, 23.22, 44.97, 66.76, 73.63, 80.79, 116.36, 118.62, 131.90, 139.03.

4-(3-(4-bromophenyl)-3,3a,4,5,6,7,8,8a-octahydrocyclohepta[*d*][1,2,3]triazol-3a-yl)morpholine 4dg: White solid; mp 189-190 °C; Yield 98%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 0.74-0.96 (m, 2H), 1.00-1.13 (m, 1H), 1.00-1.13 (m, 1H), 2.02-2.10 (m, 1H) , 2.27-2.31 (m, 2H), 2.33-2.38 (m, 2H), 2.40-2.43 (m, 1H), 2.47-2.59 (m, 1H), 3.66 (t, *J* = 4.6 Hz, 4H), 4.65 (t, *J* = .9 Hz, 1H), 7.60 (d, *J* = 9.1 Hz, 2H), 7.41 (d, *J* = 9.1 Hz, 2H); ^{13}C NMR (75 MHz,

$CDCl_3$): 23.8, 24.0, 29.6, 30.2, 30.9, 4.0, 66.8, 66.8, 77.1, 84.5, 116.2, 118.6, 132.0, 139.0; MS (ESI) m/z (%): 389.1 $(M+Na)^+$

1-(4-bromophenyl)-4,5,6,7,8,9-hexahydro-1*H*-cycloocta[*d*][1,2,3]triazole 4dh: Yellow solid; mp 131-133 °C; Yield 90%; ^{1}H NMR: (300MHz, $CDCl_3$) δ ppm : 1.47-1.56 (m, 4H), 1.71-1.84 (m, 4H), 2.73 (t, *J* = 6.4 Hz, 2H), 2.94 (t, *J* = 6.4 Hz, 2H), 7.29 (dd, *J* = 8.9 Hz ; *J* = 1.0 Hz, 2H), 7.63 (dd, *J* = 8.9 Hz ; *J* = 1.0 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): 22.0, 24.4, 25.2, 25.5, 27.4, 28.0, 123.2, 126.6, 132.5, 133.9, 135.6, 145.3; MS (ESI) m/z (%): 278.5 $(M-N_2)^+$

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