Indian Journal of Chemistry
Vol. 62, June 2023, pp. 656-661
DOI: 10.56042/ijc.v62i6.2569

Synthesis of N-aryl derived formamides using triflic anhydride

Swetha Bharamawadeyar & Vommina V Sureshbabu*

Peptide Research Laboratory, Department of Chemistry, Jnana Bharathi Campus, Bangalore University, Bangalore 560 056, India

E-mail: hariccb@gmail.com, sureshbabuvommina@rediffmail.com

Received 1 December 2022; accepted (revised) 16 May 2023

A facile and convenient one-pot protocol for the N-formylation of aryl amines has been furnished using Tf_2O. This approach involves N-formylation of anilines and its derivatives employing formic acid as a formyl source and triflic anhydride (Tf_2O) as an activator as the key step. This work highlights the ability of Tf_2O as an activating agent, includes operational simplicity, easy applicability to gram-scale preparation and to afford the N-formyl aryl amines in moderate to good yields.

Keywords: N-Formylation, Activating agent, Triflic anhydride

N-Formylation of amines is of substantial interest for synthesizing vital biologically active compounds[1(i)]. N-Formyl derivatives can be used as synthetic intermediates in the synthesis of carbamates[1(ii)], ureas[1(iii)], aryl amides[1(iv)], nitriles[1(v)], and isocyanides[1(vi)]. Also, formamides serves as predominant intermediates in the synthesis of biologically active molecules or their analogous. They are substantially used in the pharmaceuticals to make medically convenient compounds such as fluoroquinones, imidazoles, nitrogen bridged heterocycles, *etc*. N-Formamides plays a pivotal role as precursors for the synthesis of isocyanides, formamidines and oxazolidinones[2]. They are employed as Lewis base organocatalysts in allyation and hydroallyation reactions[3]. They serve as protecting groups during peptide synthesis[4].

A number of methods for the formylation of amines are available (Fig. 1). Several formylation reagents including chloral[5a], formic acid-dicyclohexyl carbodiimide (DCC)[5b], formic acid-1-ethyl-3-(3-dimethylaminopropyl)carbodiimide (EDCI)[5c], formic acid-zinc chloride ($ZnCl_2$)[5d], formic acid-polyethylene glycol 400 (PEG400)[5e], formic acid esters[5f], 2-chloro-4,6-dimethoxy[1,3,5]triazine (CDMT)[5g], dimethylformamide-sodium methoxide (DMF-NaOMe), imidazole-dimethylformamide (imidazole-DMF), formic acid-thiamine hydrochloride, propanephosphonic acid anhydride (PPAA, T3P)-formic acid[6], tetraethylorthosilicate $Si(OEt)_4$[7], thiamine hydrochloride (VB_1)[8], CO_2 with hydrosilane[9], dimethyl formamide-*tert*-butyldimethylsilyltriflate (DMF-TBSOTf)[10], dimethyl formamide-sodium *tert*-butoxide (DMF-NaO*t*Bu)[11] are available. However, some of these reagents suffer from few drawbacks such as expensive reagents, harsh reaction conditions and low isolation yields. The direct carbonylation of amines to N-formamides by using transition metal catalyst (*e.g.*, Cu, Fe, Zn, Ru, Rh, Ni)[12] is also explored employing less expensive inorganic bases including groups 1A and 2A metal hydroxides, alkoxides, carbonates, and phosphates. Still there is a need to develop a mild and practical method for N-formylation.

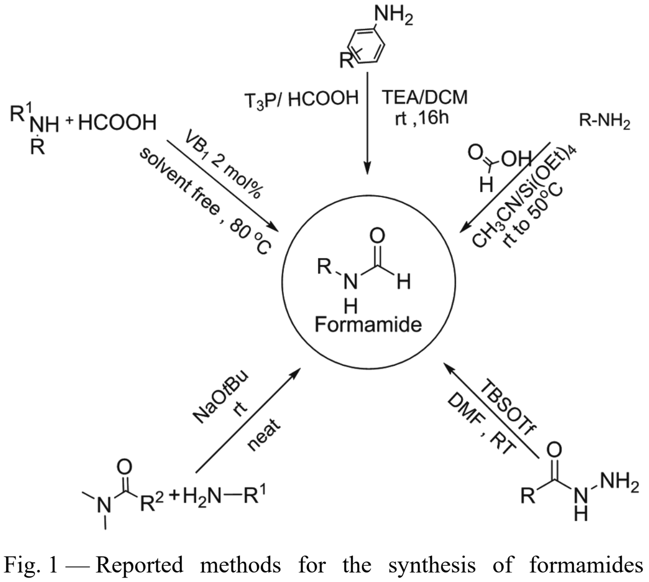


Fig. 1 — Reported methods for the synthesis of formamides (selected examples)

Trifluoromethanesulfonic anhydride (Tf_2O) is an affordable and copious reagent (Fig. 2). Tf_2O mediated one-pot conversion of carboxylic acid to its nitriles *via* primary amide[13], one-pot sequential reductive alkylation of lactam/amide using Grignard and organolithium reagents or hydrides[14], synthesis of trisubstituted oxazoles and bisoxazoles from a set of readily prepared amino acid and peptide derivatives[15] and imides using ionic liquids[16], metal free hydrosilyation of secondary amide to amine using tris(pentafluorophenyl)borane [$B(C_6F_5)_3$]-catalyzed hydrosilylation with 1,1,3,3- tetramethyldisiloxane (TMDS)[17], dealkylative conversion of sulfoxide into thiocyanate are significant[18]. This paper describes the synthesis of N-formamides employing HCO_2H-Tf_2O.

Recently Rana *et al.*, reported the one pot conversion of carboxylic acid into nitriles. This method involves the use of triflic anhydride (Tf_2O) and NH_4OH as the nitrogen source[10]. In recent years Tf_2O mediated amide bond activation has been attracted considerable attention. However, the use of Tf_2O for activation of formic acid for the synthesis of formamides had not been reported and hence we envisaged the synthesis of formamides using Tf_2O. N-Formylation of aniline and its derivatives employing formic acid as a formyl source under the mild condition was achieved using Tf_2O as an activating agent, a low cost and environmentally benign reagent. Tf_2O, also commonly known as triflic anhydride, is an acid anhydride derived from triflic acid. The mild conditions in this system enable the formylation of a variety of aniline derivatives. Herein we have developed a simple, practical, and efficient procedure for the one pot N-formylation of amines by using Tf_2O.

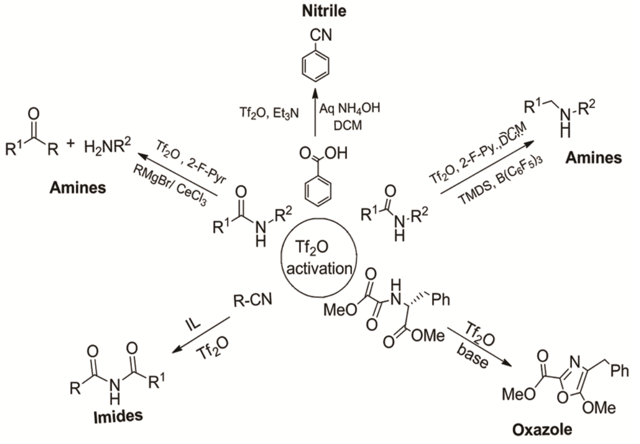
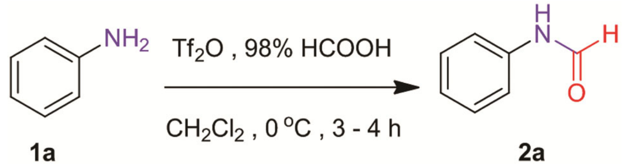


Fig. 2 — Utility of Tf_2O in organic synthesis

Results and Discussion

Initially, the reaction was commenced using aniline **1a** as the model substrate and examined its reactivity in presence of Tf_2O and HCOOH. Upon treatment of HCOOH (1.0 equiv.), pyridine (2.0 equiv.), Tf_2O (1.0 equiv.) in DCM at 0°C for 3 h with aniline **1a** accelerated N-formylation to produce **2a** (Scheme 1). The product was fully characterized by standard spectroscopic techniques (IR, ^1H and ^{13}C NMR). Encouraged by this result, we then optimized the reaction conditions by screening the solvents and bases (Table 1).

Reaction proceeded as indicated by thin layer chromatography(TLC) followed by workup and purification carried out by column chromatography. We briefly examined the effects of different bases and



Scheme 1 — Synthesis of N-formamides using Tf_2O

Table 1 — Screening optimal conditions

Entry	Solvent	Tf_2O (equiv.)	HCOOH (equiv.)	Base (equiv.)	Time (h)	Yield (%)
1	DCM	1.0	1.0	Pyridine (2.0)	3	45
2	DCM	1.0	1.5	Pyridine (2.0)	3	68
3	DCM	1.0	2.0	Pyridine (2.0)	3	76
4	DCM	1.5	2.0	Pyridine (2.0)	3	82
5	DCM	2.0	2.0	Pyridine (2.0)	3	80
6	DCM	1.5	2.0	Pyridine (2.0)	5	84
7	DCM	1.5	2.0	2-Cl-Pyridine (2.0)	3	76
8	DCM	1.5	2.0	2-F-Pyridine (2.0)	3	73
9	DCM	1.5	2.0	Et_3N (1.5)	3	91
10	DCM	1.5	2.0	DIPEA (1.5)	3	85
11	DCM	1.5	2.0	NMM (1.5)	3	83
12	Acetonitrile	1.5	2.0	Et_3N (1.5)	5	68
13	Toluene	1.5	2.0	Et_3N (1.5)	5	40
14	1,4-Dioxane	1.5	2.0	Et_3N (1.5)	5	53

their loaded amounts, solvents and temperature. It was found that the yield of **2a** could reach 45% when the reaction was performed with 1.0 equiv. of Tf_2O and 1.0 equiv. of HCOOH. Further increasing the relative amount of Tf_2O by 1.5 equiv. and HCOOH by 2.0 equiv. in DCM solvent the reaction could afford **2a** by 82% (Table 1, Entry 4) of the product but later further increase in reaction rate it was found that increase in product by 84% (Table 1, Entry 6, **2a**). Further excess amount of Tf_2O by 2.0 equiv. and HCOOH by 2.0 equiv. was ineffective (Table 1, Entry 5). It was found that, there is no significant influence on the yield of **2a**. Treatment of **1a** with 1.5 equiv. of Et_3N was also examined. Finally, the optimized reaction condition for the efficient conversion was achieved when 1.5 equiv. of Et_3N and 2.0 equiv. of HCOOH were used.With this condition, we obtained yield 91% of **2a** without any formation of noticeable impurities. The incorporation of pyridine, 2-chloropyridine, 2-fluropyridine, DIPEA and NMM as a non-nucleophilic and slightly basic additives in the reaction media resulted in slow reaction and poor yields of **2a**/crucial to achieve an appreciable level of efficiency. We thus explored base additives finding that Et_3N was the optimal choice for ease of purification. With this understanding we further studied the effect of solvent on reaction profile and yield. The reaction using solvents such as acetonitrile, toluene or 1,4-dioxane afforded poor yields (Table 1, Entry 12, 13 and 14) compared with dichloromethane.

After optimizing the reaction conditions, we turned our attention to examine the scope of various substrates. A series of aniline derivatives bearing electron donating groups (Me and OMe) reacted smoothly to give the corresponding formamides with good yield up to 91%. But aniline derivatives bearing electron withdrawing group (Cl, F and CN) did not have much influence on the reaction efficiency with slight drop in reaction yield was observed. Thus, performing the formylation of aniline and its derivatives with 98% HCOOH (2.0 equiv.) in the presence of Tf_2O (1.5 equiv.) and Et_3N (1.5 equiv.) in dichloromethane afforded 75-91% yield of desired product (Table 2).

Plausible mechanism

In the plausible mechanism, initially in the first step, Et_3N abstracts the proton from formic acid **I**, further nucleophilic attack of the formate **II** on triflic anhydride leads to trifluoromethanesulfonic anhydride **III** wherein nitrogen source as a aryl amine was added which displaces the triflate leading to the formation of desired formamide **IV**. The elimination of triflate ions during the reaction was assisted by protonated triethylamine (Fig. 3).

Materials and Methods

All commercially available reagents were used as received without further purification. The solvents were purified and dried by standard procedures prior to use. Reaction progress was monitored by thin layer chromatography (TLC) performed on aluminium plates coated with silica gel 60 F254 (Merck). High resolution mass spectra were recorded on a Micromass Q-TOF micromass spectrometer using electron spray ionization mode. ^1H and ^{13}C NMR spectra were recorded on a Bruker AMX 400 MHz and 100 MHz spectrometer, respectively in DMSO-d_6 using TMS as internal standard. For purification of products, column chromatography was performed over silica gel (100-200 mesh) using ethyl acetate and hexane mixture as eluant. Evaporation of solvents was performed under reduced pressure with a Büchi rotary evaporator. Melting points were determined in an open capillary using VEEGO, model: VMP-DS.

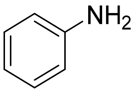
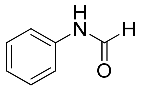
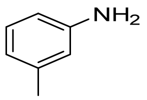
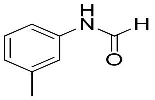
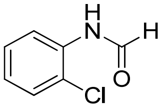
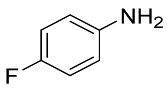
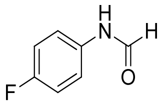
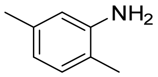
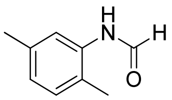
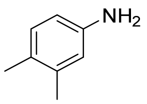
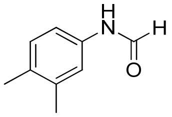
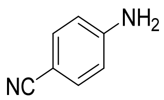
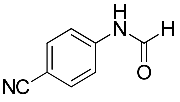
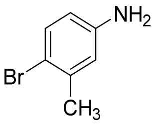
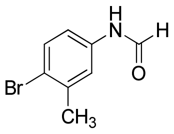
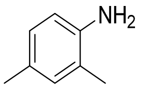
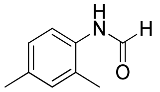
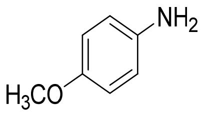
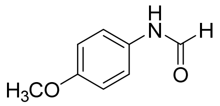
Experimental Section

General synthetic procedure for the preparation of formamide derivatives

98% Formic acid in DCM was initially cooled to 0°C. Tf_2O (1.5 equiv.) and Et_3N (1.5 equiv.) were added. And, the reaction mixture was stired for 15-20 min. Later, aniline (1.0 equiv.) was added and the reaction mixture was stirred for another 4 h. The course of the reaction was monitored by TLC. The solvent was evaporated *in vacuo*. The residue was dissolved in ethyl acetate (EtOAc). The organic layer was washed with 10% HCl, followed by 10% Na_2CO_3 and then brine. The organic layer was dried over anhyd. Na_2SO_4, filtered and concentrated under reduced pressure to obtain the desired product. The product was purified by column chromatography, eluting with EtOAc-hexane.The resulted formamides are characterized by standard spectroscopic techniques ^1H and ^{13}C NMR, and HRMS.

***N*-Phenylformamide, 2a**: Yellow oil. Yield 91%. ^1H NMR (400 MHz, DMSO-d_6): δ 9.99(s,1H), 8.20 (d, 1H), 7.34-7.27 (m,3H), 7.05 (d,2H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 162.3, 130.1, 129.6, 120.2, 118.9, 116.6, 115.1; HRMS: *m/z* Calcd for C_7H_8NO [M+H]: 122.0606. Found: 122.0610.

Table 2 — List of N- formamides derived from aniline/Tf_2O as an activating agent **(2a-j)**

Entry	Amine	N-Formamide	Yield (%)
1	 **1a**	 **2a**	91%
2	 **1b**	 **2b**	85%
3	 **1c**	 **2c**	79%
4	 **1d**	 **2d**	80%
5	 **1e**	 **2e**	86%
6	 **1f**	 **2f**	88%
7	 **1g**	 **2g**	75%
8	 **1h**	 **2h**	80%
9	 **1i**	 **2i**	87%
10	 **1j**	 **2j**	90%

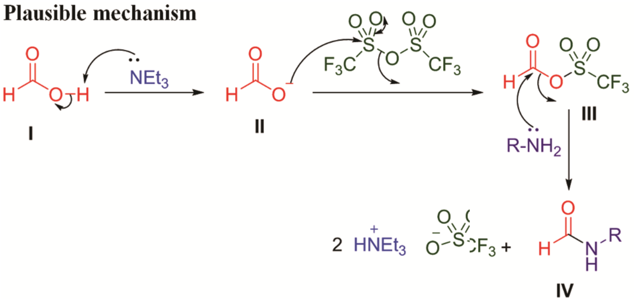


Fig. 3 — Plausible mechanism for formamide formation

***N*-m-Tolyformamide, 2b**: Yellow oil. Yield 85%. ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.07 (s, 1H), 8.25 (d,1H), 7.38 (t, *J* = 16Hz, 1H), 7.18 (t, *J* = 8Hz,1H), 7.00-6.87 (m, 2H), 2.27 (s, 3H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 159.4, 138.0, 128.6, 124.2, 119.5, 118.0, 116.2, 21.1; HRMS: *m/z* Calcd for $C_8H_{10}NO$ [M+H]: 136.0762. Found: 136.0768.

***N*-(2-Chlorophenyl)formamide, 2c**: White solid. Yield 79%. m.p.78.8-79.8°C. IR: 3248, 2900, 1701, 738 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 9.88 (s,1H), 8.35 (d, *J*=4Hz, 1H), 8.1 (dd, *J*=8Hz, 1H),7.49 (dd, *J*=8Hz, *J*=4Hz, 1H), 7.35-7.31 (m,1H), 7.17-7.13 (m,1H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 160.3, 134.2, 130.0, 129.4, 127.6, 125.5, 123.2; HRMS: *m/z* Calcd for C_7H_7ClNO [M+H]: 156.0216. Found: 156.0225.

***N*-(4-Fluorophenyl)formamide, 2d**: Pale brown solid. Yield 80%. HRMS: *m/z* Calcd for C_7H_7FNO [M+H]: 140.0512. Found: 140.0500.

***N*-(2,5-Dimethylphenyl)formamide, 2e**: Off white solid. Yield 86%. m.p 107.8-108.9°C. IR: 3244, 2968, 1644 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 9.48 (s,1H), 8.26 (d, *J*=4Hz, 1H), 7.57 (s,1H),7.08 (t, *J*=8Hz, 1H), 6.86 (d, *J*=8Hz, 1H),2.24 (d, *J*=4Hz, 3H),2.17 (d, *J*=8Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 159.6, 130.5, 130.1, 125.8, 125.2, 123.2, 122.4, 20.6, 17.3.

***N*-3,4-Dimethylphenyl)formamide, 2f**: Light yellow solid. Yield 88%. m.p.65.6-67.7°C. ^{1}H NMR (400 MHz, DMSO-d_6): δ 9.97 (s, 1H), 8.20 (d, *J*= 4Hz, 1H), 7.35 (s, 1H),7.29 (dd, *J*=8Hz, J=4Hz, 1H), 7.05 (d, *J*=8Hz, 1H),2.18 (s,3H), 2.16 (s, 3H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 159.2, 130.1, 129.6, 120.2, 118.9, 116.6, 115.1, 19.5, 18.7; HRMS: *m/z* Calcd for $C_9H_{12}NO$ [M+H]: 150.0919. Found: 150.0916.

***N*-(4-Cyanophenyl)formamide, 2g**: Yellow solid. Yield 75%. m.p.180.2-182.2°C. IR: 3205, 2900, 2221, 1696 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.65 (s, 1H), 8.36 (d, *J*=4Hz, 1H), 7.80-7.74 (m, 4H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 160.4, 142.2, 133.4(2C), 119.2(2C), 117.0, 105.4; HRMS: *m/z* Calcd for $C_8H_7N_2O$ [M+H]: 147.0558. Found: 147.0550.

***N*-(4-Bromo-3-methylphenyl)formamide, 2h:**Brown solid. Yield 80%. m.p.55.5-57.7°C. ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.21 (s, 1H), 8.27 (d , *J*=4Hz, 1H), 7.57 (d, 1H),7.48 (t, *J*=8Hz, 1H), 7.36 (dd, *J*=8Hz, J=4Hz, 1H), 2.30 (s, 3H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 159.9, 137.7, 132.7, 132.3, 121.3, 119.7, 118.6, 22.5; HRMS: *m/z* Calcd for C_8H_9BrNO [M+H]: 213.9868. Found: 213.9854.

***N*-(2,4-Dimethylphenyl)formamide, 2i**: White solid. Yield 87%. m.p.112.8-113.4°C. ^{1}H NMR (400 MHz, DMSO-d_6): δ 9.44 (s, 1H), 8.25 (d, 1H), 7.56 (d, *J*=8Hz, 1H), 7.03 (t, *J*=4Hz, 1H),6.97 (t, *J*=8Hz, 1H),2.23 (d, *J*=4Hz, 3H),2.18 (d, *J*=8Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 159.7, 131.3, 130.8, 127.1, 126.4, 122.9, 122.3, 20.3, 17.4; HRMS: *m/z* Calcd for $C_9H_{12}NO$ [M+H]: 150.0919. Found: 150.0921.

***N*-(4-Methoxyphenyl)formamide, 2j**: Yellow solid. Yield 90%. m.p.78.0-79.0°C. IR: 3325, 2849, 1650, 1027, 1231 cm^{-1}; ^{1}H NMR (400 MHz, DMSO-d_6): δ 10.03 (s,1H), 8.20 (d,1H), 7.50 (dd, *J*=8Hz, *J*=4Hz, 2H), 6.88 (dd, *J*=8Hz, *J*=4Hz, 2H),3.71 (d, *J*=4Hz, 3H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 159.0, 155.3, 131.4, 120.6(2C), 113.9(2C), 55.1.

Conclusion

In conclusion, we have demonstrated a facile conversion of a broad range of aniline derivatives into their corresponding formamides by employing triflic anhydride (Tf_2O) as activating agent. In summary, we have developed a simple, practical, and efficient procedure for the synthesis of N-formyl derivatives of aniline employing Tf_2O. The advantage of this method is the use of less expensive and commercially available starting materials, stable, non-toxic reagents and easy work-up with improved yield.

Supplementary Information

Supplementary information is available in the website http://nopr.niscpr.res.in/handle/123456789/58776.

Acknowledgement

The authors thank the Council of Scientific and Industrial Research, New Delhi for financial assistance.

References

1 (i) Huang H Y, Lin X Y, Yen S Y & Liang C F, *Org Biomol* Chem, 18 (2020) 5726.
  (a) Campos F, Bosch M P & Guerrero A, *Tetrahed Asym*, 11 (2000) 2705.
  (b) Ma G, Zancanella M, Oyola Y, Richardson R D, Smith J W & Romo D, *Org Lett*, 8 (2006) 4497.
  (c) Dunetz J R, Magano J & Weisenburger G A, *Org Process Res Dev*, 20 (2016) 140.
  (d) Lundberg H, Tinnis F, Selander N & Adolfsson H, *Chem Soc Rev,* 43 (2014) 2714.
 (ii) (a) Barve B D, Wu Y C, El-Shazly M, Chuang D W, Chung Y M, Tsai T H, Wu S F, Korinek M,
  (a) Du Y C, Hsieh C T, Wang J J & Chang F R, *Eur J Org Chem*, 2012 (2012) 6760.
  (b) Reddy N V, Prasad K R, Reddy P S, Kantam M L & Reddy K R, *Org Biomol Chem,* 12 (2014) 2172.
 (iii) (a) Kondo T, Kotachi S, Tsuji Y, Watanabe Y & Mitsudo T, *Organometallics*, 16 (1997) 2562.
  (b) Krishnakumar V, Chatterjee B & Gunanathan C, *Inorg Chem*, 56 (2017) 7278.
 (iv) (a) Schnyder A, Beller M, Mehltretter G, Nsenda T, Studer M & Indolese A F, *J Org Chem*, 66 (2001) 4311.
  (b) Jo Y, Ju J, Choe J, Song K H & Lee S, *J Org Chem*, 74 (2009) 6358.
 (v) Wang X, Jiang N, Zhao S, Xi S, Wang J, Jing T, Zhang W, Guo M, Gong P & Zhai X, *Bioorg Med Chem*, 25 (2017) 886.
 (vi) (a) Obrecht R, Herrmann R & Ugi I, *Synthesis*, (1985) 400.
  (b) Porcheddy A, Giacomelli G & Salaris M, *J Org Chem*, 70 (2005) 2361.
  (c) Ichikawa Y, Minami T, Kusaba S, Saeki N, Tonegawa Y, Tomita Y, Nakano K, Kotsuki H & Masuda T, *Org Biomol Chem,* 12 (2014) 3924.
  (d) Wang X, Wang Q G & Luo Q L, *Synthesis*, 47 (2015) 49.
2 Kandula V, Gudipatia R, Chatterjeeb A, Yennama S & Behera M, *Syn Open,* 2 (2018) 176.
3 Satasia, S P, Kalaria P N & Raval D K, *J Mol Cat A Chem,* 391 (2014) 41.
4 Hartines J & Laur J, *Synthesis,* (1982) 979. (Kindly provide Lei M, Maa L & Hua L, *Tetrahedron Lett,* 51 (2010) 4186.
(a) Blicke F F & Lu C J, *J Am Chem Soc*, 74 (1952) 3933.
(b) Waki J & Meinhofer J, *J Org Chem*, 42 (1977) 2019.
(c) Chen F M F & Benoiton N L, *Synthesis,* (1979) 709.
(d) Shekhar A C, Kumar A R, Sathaiah G, Paul V L, Sridhar M & Rao P S, *Tetrahedron Lett*, 50 (2009) 7099.
(e) Das B, Krishnaiah M, Balasubramanyam, P, Veeranjaneyulu B & Nandankumar D, *Tetrahedron Lett*, 49 (2008) 2225.
(f) (a) Yale H L, *J Org Chem*, 36 (1971) 3238.
 (b) Kisfaludy, L & Laszlo, O, *Synthesis*, (1987) 510. (Kindly
 (c) Duezek W, Deutsch J, Vieth S & Niclas H J, *Synthesis,* (1996) 37. (g) Luca L D, Giacomelli G, Porcheddu A & Salaris M, *Syn lett*, (2004) 2570. Venu Kandula, Ramakrishna Gudipatia, Anindita Chatterjeeb, Satyanarayana Yennama & Manoranjan Behera, *Syn Open, 2* (2018) 176–179.
(g) Gerack C J & McElwee-White L, *Molecules, 19* (2014) 7689.
(h) Lei M, Ma L & Hu L,*Tetrahedron Lett*, *51* (2010) 4186.
(i) Suchy M, Elmehriki A A H & Hudson R H E, *Org Lett*, *13* (2011) 3952.
(j) Olah G A, Ohannesian L & Arvanaghi M, *Chem Rev*, *87* (1987) 671.
5 Nishikawa Y, Nakamura H, Ukai N, Adachi W & Hara O, *Tetrahedron Lett*, 58 (2017) 860.
6 Lei M, Lei Maa L & Hua L, *Tetrahedron Lett,* 51 (2010) 4186.
7 Li Z, Yu Z, Luo X, Li C, Wu H, Zhao W, Li H & Yang S, *RSC Adv*, 10 (2020) 33972.
8 Sakurai M, Kawakami R & Kiharaa N, *Tetrahedron Lett*, 60 (2019) 1291.
9 Zhang R, Zhang J C, Zhang W Y, He Y Q, Cheng H, Chen C & Gu Y C, *Synthesis*, 52 (2020) 3286.
10 Li W & Wu X F, *Chem Eur J*, 21 (2015) 14943.
11 Rana A, Kumar V, Tiwari L, Thakur A, Meena C L & Mahajan D, *Syn Open*, 2 (2018) 180.
12 Liao J C, Xiao K J, Zheng X & Huang P Q, *Tetrahedron*, 68 (2012) 5297e.
13 Thalhammer A, Mecinovic J & Schofield C J, *Tetrahedron Lett*, 50 (2009) 1045.
14 Khodaei M M & Nazari E, *Tetrahedron Lett,* 53 (2012) 2881.
15 Huang P Q, Lang Q W & Wang Y R, *J Org Chem*, 81 (2016) 4235.
16 Todorović U, Klose I & Maulide N, *Org Lett*, 23 (2021) 2510.