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Stereoselective synthesis of (*Z*)-trifluoromethyl enamines and their Lewis acid-mediated conversion into (*E*)-isomers

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Abstract—(*Z*)-β-Trifluoromethyl enamines were prepared in high yield stereoselectively by reaction of 2-bromo-3,3,3-trifluoropropene with *N*-alkyl toluenesulfonamides and potassium *t*-butoxide in one pot via Michael addition and elimination processes. The (*Z*)-β-trifluoromethyl enamines could be converted to the corresponding thermodynamically stable (*E*)-isomers promoted by Lewis acid catalysts at room temperature or thermal isomerization.

1. Introduction

Organofluorine compounds have found increasing use in the area of agrochemicals, pharmaceuticals, polymers and new materials.[1] Fluorine-containing enamines are versatile building blocks for the introduction of fluorinated groups into various new fluorine-containing heterocyclic compounds and natural products.[2] A number of new methods have been developed to prepare the α-fluorine-containing enamines in addition to classical methods based on the reactions of perfluoroalkenes[3] or 1*H*-perfluoroalkynes[4] with amines. Recently, Portella and Iznaden obtained perfluorinated enaminoesters in good yields by the reaction of α-*H*-perfluoroesters with secondary amines.[5] Bégué prepared α-trifluoromethylated enamines (*Z*/*E* mixture) by condensation of trifluoroacetamides with alkylidene phosphoranes.[6] Bravo has reported the synthesis of α-(fluoroalkyl)-α-sulfinyl enamines by aza-Wittig reaction of triphenyliminophosphoranes with the corresponding α-fluorinated-α′-sulfinyl ketones and their further applications.[7] However, the synthesis of β-trifluoromethylated enamines has, for a long time, been difficult because the α-CF_3-attached carbanion would lead to a defluorination process. For example, Uneyama only obtained N-trimethylsilylated β,β-difluoroenamines from trifluoromethyl imines by an electrochemical reduction.[8] To the best of our knowledge, only Yamanaka synthesized β-trifluoromethyl enamines through the reaction of *N*-(2,3,3,3-tetrafluoro-1-propenyl)-trimethyl ammonium iodide with secondary amines,[9] but it is far from ideal. The reported methods suffered from lack of availability of the starting materials, low yields and poor stereoselectivity. Therefore, it is of great value to develop more facile and effective methods for preparing β-trifluoromethyl enamines.

Herein we wish to introduce a convenient and stereoselective access to (*Z*)-β-trifluoropropenamines in one pot from the readily available 2-bromo-trifluoropropene (BrTFP, 1) in high yields. The (*Z*)-isomers were converted to thermodynamically more stable (*E*)-isomers by heating or Lewis acid catalysis.

2. Results and discussion

It has been reported that BrTFP (**1**) reacted with thiophenol to yield the corresponding trifluoromethyl vinyl sulfide[10] or with alcohols to give (*Z*)-3,3,3-trifluoropropenyl alkyl ethers in excellent yields under alkaline conditions.[11] Those results prompted us to investigate the preparation of trifluoromethyl enamines from the readily available **1**. Initially, we attempted to prepare trifluoromethyl enamines by the direct reaction of **1** with alkylamines and potassium hydroxide in ethanol, but only 3,3,3-trifluoropropenyl ethyl ether was obtained. It is obvious that ethanol participated in the reaction was faster than the amine. After many trials, we found that the potassium N-substituted *p*-toluenesulfonamides reacted with BrTFP (**1**) smoothly. As a model reaction, *N*-propenyl *p*-toluenesulfonamide **2a** was treated with potassium *t*-butoxide in a mixture of dimethylsulfoxide and *t*-butyl alcohol to give a solution of potassium *N*-propenyl *p*-toluenesulfonamide at room temperature, to which was added BrTFP (**1**) at 80°C for 5 h to give a stable α-trifluoromethyl enamine **3a** in 82% yield as a single product (Scheme 1). The reactions extended to various

Keywords: trifluoromethyl enamines; sulfonamide; stereoselective; isomerization.

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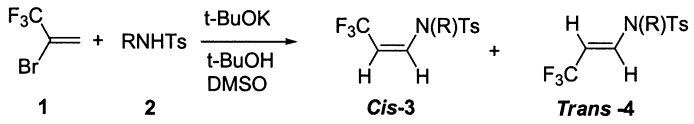


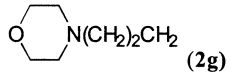
Scheme 1.

substrates of *N*-alkyl or *N*-aryl *p*-toluenesulfonamide are summarized in Table 1. It was shown that most of the sulfonamides **2b**–**h** reacted cleanly to afford the corresponding (*Z*)-β-trifluoromethyl enamines **3b**–**h** in high yields (entries 2–7). The steric hindrance of the *N*-α-methylbenzyl *p*-toluenesulfonamide **2h** (entry 8) gave a low yield (47%) of **3h**. All of the reactions gave (*Z*)-configuration of the enamines, which was assigned due to the *cis*-hydrogen-coupling constant of the double bond (J_{H-H}=10.9 Hz).

We hypothesized that the mechanism of this unusual reaction would be Michael addition followed by elimination (Scheme 2). The strong electron-withdrawing property of the trifluoromethyl group of BrTFP (**1**) causes high electron deficiency of the double bond. The amide **2** underwent Michael addition to give an adduct, confirmed in one example by quenched the reaction after 1 h at room temperature. Thus, intermediate **5** was isolated, which had a signal at δ_{TFA} −6.28 ppm. While **5** was treated with *t*-BuOK in DMSO, the δ_{TFA} −6.28 ppm signal gradually converted into −23 ppm indicating formation of **3a**.

To account for the *cis*-preference of CF_3 and sulfonamide on the double bond under the kinetic control elimination of hydrogen bromide can be rationalized in terms of stabilizing π'-type orbital interactions between the CF_3 and enamine fragments as depicted in **6** (Scheme 2). Bumgardner has rationalized the stereochemistry of substituted trifluoromethyl ethylene to the secondary orbital interaction of the LUMO (π^*CF_3) and HOMO (π') of vinyl fragment.[12] In **6** the enamine moiety is presented by the HOMO π', and the CF_3 group by its LUMO π^*CF_3. The $\pi'-\pi^*CF_3$ interaction is expected to be more stabilizing for the *cis* than the *trans* arrangement of CF_3 and sulfonamide. It could be predicted that if the reaction were carried out with the nitrogen atom delocalized by conjugated with aromatic π orbital with a small contribution for secondary-orbital of the $\pi'-\pi^*CF_3$ interaction, the major product could be the normal thermodynamically more stable (*E*)-isomer as major product. This hypothesis was confirmed when the reaction was carried out with uracil (**7**) and thymine (**8**) to give *Z*/*E*-isomers ratios of 15:85 (65% yield) (Scheme 2).

Table 1. Preparation of (*Z*)-β-trifluoromethyl enamines (**3**) and (*E*)-β-trifluoromethyl enamines (**4**)

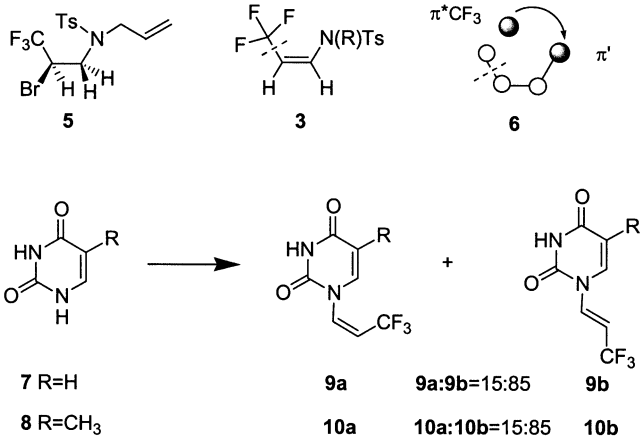
Entry	R in amide **2**	Time[a] (h)	Yield[b,c] (%)	
			(*Z*)-**3**	(*E*)-**4**
1	CH_2=CH_2CH_2 (**2a**)	5	82 (**3a**)	92 (**4a**)
2	$CH_3CH_2CH_2$ (**2b**)	4	82 (**3b**)	96 (**4b**)
3	$CH_3(CH_2)_4CH_2$ (**2c**)	4	79 (**3c**)	96 (**4c**)
4	Phenyl (**2d**)	5	80 (**3d**)	95 (**4d**)
5	Benzyl (**2e**)	3	88 (**3e**)	97 (**4e**)
6	$CH_3O(CH_2)_2CH_2$ (**2f**)	4	92 (**3f**)	97 (**4f**)
7	 (**2g**)	8	86 (**3g**)	95 (**4h**)
8	α-Methylbenzyl (**2h**)	4	47 (**3h**)	–

[a] Reaction was carried out by treatment of BrTHF (**1**) (1.2 equiv.), *t*-BuOK (1.4 equiv.) and toluene sulfonamide (0.8 equiv.) in DMSO/*t*-BuOH (2:1).
[b] Reaction was carried out by heating *cis*-**3** in decahydronaphthene at 190°C for 1 h.
[c] Isolated yield.

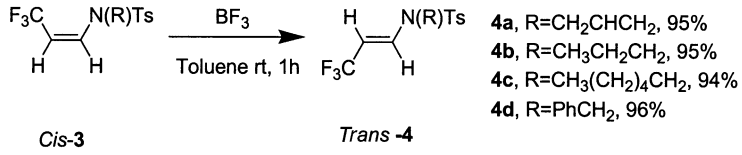
It is well known that *Z*-double bonds can be easily isomerized into thermodynamically more stable isomers by thermal isomerization or phtoisomerization via a free radical mechanism. When (*Z*)-β-trifluoromehtylated enamines were heated in decahydronaphthene at 190°C for 1 min, they were exclusively converted into the corresponding (*E*)-isomers **4** (Table 1). It was reported that Lewis acid could promote inversion of double bond while irradiating with UV light.[13] In the case of conversion of the *cis*-enamines **3** to *trans*-enamines **4**, we found that (*Z*)-β-trifluoromethylenamines **3** were transferred into (*E*)-isomers in excellent yield with catalytic amounts of $BF_3{\cdot}Et_2O$ in toluene at room temperature without irradiating with UV lamp. The conversion reaction was complete in less than one hour (Scheme 3).

3. Conclusion

In summary, we have successfully developed a stereoselective method for the preparation (*Z*)-β-trifluoromethyl enamines from the readily available 2-bromotrifluoropropene in high yield. We found that $BF_3{\cdot}Et_2O$ could promote the rearrangement of (*Z*)-β-trifluoromethyl enamines into thermodynamically more stable *E*-isomers at room temperature without irradiation with UV lamp or by thermal isomerization in decahydronaphthene. The reaction was processed under very mild conditions and simple manipulations. The present reaction constitutes a new facile route to (*Z*) or (*E*)-β-trifluoromethyl enamines



Scheme 2.



Scheme 3.

respectively, which are difficult to prepare by other methods.

4. Experimental

^{1}H NMR spectra were recorded on a VXL-300 instrument. The chemical shifts are reported as δ values in ppm relative to tetramethylsilane as internal standard. ^{19}F NMR spectra were obtained on 56.4 MHz spectrometer with trifluoroacetic acid (δ 0.00) as an external standard; downfield shifts were designated negative. IR spectra were recorded on a Perkin–Elmer 983 FT-IR spectrometer. Mass spectral measurements were performed on a Fining 4021 or Fining MAT 8403 gas chromatography/mass spectrometer at 70 eV. Elemental analyses were carried out on a MOD-1106 elemental analyzer.

4.1. General procedure for synthesis of *N*-[(*Z*)-3,3,3-trifluoropropenyl]-*N*-alkyl-*p*-toluenesulfonamide (3)

N-Alkyl *p*-toluenesulfonamide (**2**) (8 mmol) in the mixture solvent of DMSO (20 mL) and *t*-butyl alcohol (10 mL) was added potassium *t*-butoxide (1.4 equiv.) at room temperature with stirring. When the reaction mixture was heated to 80°C, 2-bromotrifluoropropene (**1**) (1.2 equiv.) was added dropwise. The mixture was kept at 80°C for 5 h. After cooling to room temperature, the mixture was poured into water (100 mL) and extracted with ethyl acetate (3×50 mL). The combined extracts was washed with brine and dried over Na_2SO_4. After removal of solvent under reduced pressure, the residue was purified on silica gel column chromatography eluting with ethyl acetate and petroleum ether (1:20) to afford **3**.

4.1.1. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-propenyl-*p*-toluenesulfonamide (3a). Colorless oil; (Found: C, 51.29; H, 4.62; N, 4.60. $C_{13}H_{14}F_3NO_2S$ requires C, 51.14; H, 4.59; N, 4.59%); ν_{max} (liquid film) 1163, 1114, 1090 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −23 (CF_3, d, J=9.5 Hz); δ_H (300 MHz, $CDCl_3$) 2.44 (3H, s, CH_3), 4.17 (2H, d, J=7.7 Hz, CH_2CH=CH_2), 4.93–5.03 (1H, m, CH_2CH=CH_2), 5.11–5.19 (2H, m, CH_2CH=CH_2), 5.64–5.73 (1H, m, CF_3CH=CH), 6.73 (1H, d, J=10.2 Hz, CF_3CH=C*H*), 7.33 (2H, d, J=8.4 Hz, 2×Ph-*H*), 7.70 (2H, d, J=8.4 Hz, 2×Ph-*H*); *m*/*z* (EI) 305 (3, M$^+$), 91 (100%).

4.1.2. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-propanyl-*p*-toluenesulfonamide (3b). Colorless oil; (Found: C, 50.49; H, 5.22; N, 4.58. $C_{13}H_{16}F_3NO_2S$ requires C, 50.87; H, 5.21; N, 4.56%); ν_{max} (liquid film) 1652, 1357, 1265, 1177, 1160, 1116 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −23 (CF_3, d, J=9.5 Hz); δ_H (300 MHz, $CDCl_3$) 0.85 (3H, t, J=7.4 Hz, CH_2CH_2 CH_3), 1.57–1.67 (2H, m, CH_2CH_2 CH_3), 2.44 (3H, s, CH_3), 3.43 (2H, t, J=7.9 Hz, CH_2CH_2 CH_3), 4.92–4.98 (1H, m, CF_3CH=CH), 6.74 (1H, d, J=10.8 Hz, CF_3CH=C*H*), 7.34 (2H, d, J=8.36 Hz, 2×Ph-*H*), 7.68 (2H, d, J=8.36 Hz, 2×Ph-*H*); *m*/*z* (EI) 307 (20, M$^+$), 155 (100), 91 (93%).

4.1.3. *N*-[(*E*)-3,3,3-Trifluoropropenyl]-*N*-hexanyl-*p*-toluenesulfonamide (3c). Colorless oil; (Found: C, 54.91; H, 6.33; N, 4.12. $C_{16}H_{22}F_3NO_2S$ requires C, 55.01; H, 6.30; N, 4.01%); ν_{max} (liquid film) 1652, 1358, 1163, 1114 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −23.2 (CF_3, d, J=9.5 Hz); δ_H (300 MHz, $CDCl_3$) 0.86 (3H, t, J=6.9 Hz, CH_3), 1.19–1.23 (6H, m, CH_2), 1.59 (2H, m, CH_2), 2.43 (3H, s, CH_3), 3.45 (2H, t, J=7.9 Hz, CH_2), 4.91–4.99 (1H, m, CF_3CH=CH), 6.73 (1H, d, J=10.8 Hz, CF_3CH=C*H*), 7.33 (2H, d, J=8.4 Hz, 2×Ph-*H*), 7.67 (2H, d, J=8.4 Hz, 2×Ph-*H*); *m*/*z* (EI) 349 (5, M$^+$), 265 (59.57), 155 (100), 91 (97%).

4.1.4. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-phenyl-*p*-toluenesulfonamide (3d). White solid; mp 93°C; (Found: C, 56.13; H, 3.92; N, 3.95. $C_{16}H_{14}F_3NO_2S$ requires C, 56.30; H, 4.11; N, 4.11%); ν_{max} (Nujol) 1658, 1373, 1363, 1171, 1144 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −20.5 (CF_3, d, J=9.8 Hz); δ_H (300 MHz, CD_3COCD_3) 2.40 (3H, s, CH_3), 5.21–5.27 (1H, m, CF_3CH=CH), 6.99 (2H, d, J=7.5 Hz, CF_3CH=C*H*), 7.01–7.40 (5H, m, 5×Ph-*H*), 7.45 (2H, d, J=7.5 Hz, 2×Ph-*H*), 7.52 (2H, d, J=7.5 Hz, 2×Ph-*H*); *m*/*z* (EI) 341 (7, M$^+$), 91 (100%).

4.1.5. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-benzyl-*p*-toluenesulfonamide (3e). White solid; mp 80°C; (Found: C, 57.41; H, 4.53; N, 4.05. $C_{17}H_{16}F_3NO_2S$ requires C, 57.46; H, 4.51; N, 3.94%); ν_{max} (Nujol) 1681, 1363, 1167, 1145, 1115 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −22.5 (CF_3, d, J=9.5 Hz); δ_H (300 MHz, $CDCl_3$) 2.41 (3H, s, CH_3), 4.71 (2H, s, CH_2), 5.01–5.08 (1H, m, CF_3CH=CH), 6.66 (1H, d, J=10.2 Hz, CF_3CH=C*H*), 7.20–7.27 (5H, m, 5×Ph-H), 7.32 (2H, d, J=7.5 Hz, 2×Ph-*H*), 7.62 (2H, d, J=7.5 Hz, 2×Ph-*H*); *m*/*z* (EI) 355 (2, M$^+$), 91 (100%).

4.1.6. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-[(3-methoxy)-propanyl]-*p*-toluenesulfonamide (3f). White solid; (Found: C, 49.75; H, 5.35; N, 4.45. $C_{14}H_{18}F_3NO_3S$ requires C, 49.85; H, 5.34; N, 4.15%); ν_{max} (Nujol) 1653, 1358, 1164, 1115 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −22.5 (CF_3, d, J=9.5 Hz); δ_H (300 MHz, $CDCl_3$) 1.85–1.90 (2H, m, CH_2), 2.43 (3H, s, CH_3), 3.30 (3H, s, OCH_3), 3.37 (2H, t, J=6.1 Hz, CH_2N), 3.56 (2H, t, J=7.5 Hz, CH_2O), 4.98–5.05 (1H, m, CF_3CH=CH), 6.70 (1H, d, J=10.6 Hz, CF_3CH=C*H*), 7.33 (2H, d, J=8.1 Hz, 2×Ph-*H*), 7.68 (2H, d, J=8.1 Hz, 2×Ph-*H*); *m*/*z* (EI) 337 (2, M$^+$), 124 (100%).

4.1.7. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-[1-(3-morpholinyl)propanyl]-*p*-toluenesulfonamide (3g). (Found: C,

52.20; H, 5.87; N, 7.21. $C_{17}H_{23}F_3N_2O_3S$ requires C, 52.04; H, 5.87; N, 7.14%); ν_{max} (Nujol) 1681, 1164, 1144, 1113 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −23.0 (CF_3, d, J=9.4 Hz); δ_H (300 MHz, $CDCl_3$) 1.79–1.88 (2H, m, CH_2), 2.31 (2H, t, J=6.9 Hz, CH_2), 2.38 (4H, t, J=4.6 Hz, CH_2), 2.44 (3H, s, CH_3), 3.53 (2H, t, J=7.8 Hz, CH_2), 3.68 (4H, t, J=4.7 Hz, CH_2), 4.96–5.01 (1H, m, CF_3CH═CH), 6.76 (1H, d, J=10.8 Hz, CF_3CH═C*H*), 7.35 (2H, d, J=8.1 Hz, 2×Ph-H), 7.68 (2H, d, J=8.1 Hz, 2×Ph-*H*); *m/z* (EI) 392 (13, M^+), 100 (100%).

4.1.8. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-[(1*R*)-1-phenylethyl]-*p*-toluenesulfonamide (3h). Mp 85°C $[\alpha]_{20}^{D}$= −50.2° (*c*, 2.0, $CHCl_3$); (Found: C, 58.18; H, 4.79; N, 3.66. $C_{18}H_{18}F_3NO_2S$ requires C, 58.54; H, 4.88; N, 3.79%); ν_{max} (Nujol) 1674, 1169, 1149, 1110 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −18.5 (CF_3, d, J=7.9 Hz); δ_H (300 MHz, $CDCl_3$) 1.50 (3H, d, J=7.1 Hz, CHCH_3), 2.43 (3H, s, CH_3), 5.16 (1H, q, J=7.1 Hz, C*H*CH$_3$), 5.53–5.59 (1H, m, CF_3CH═CH), 5.88 (1H, d, J=9.0 Hz, CF_3CH═C*H*), 7.03–7.06 (2H, m, 2×Ph-H), 7.19–7.24 (3H, m, 3×Ph-H), 7.29 (2H, d, J=8.1 Hz, 2×Ph-H), 7.61 (2H, d, J=8.1 Hz, 2×Ph-*H*); *m/z* (EI) 369 (0.5, M^+), 105 (100%).

4.1.9. 1-[(*Z*)-3,3,3-Trifluoro-1-propenyl]-2,4(3*H*)-pyrimidinedione (9a). Mp 161°C; (Found: C, 40.87; H, 2.29; N, 13.39. $C_7H_5F_3N_2O_2$ requires C, 40.78; H, 2.43; N, 13.59%); ν_{max} (Nujol) 3026, 1737, 1699, 1 76, 1383, 1193, 1117 cm^{-1}; δ_F (56.4 MHz, Acetone-d_6) −18.5 (CF_3, d, J=9.0 Hz); δ_H (300 MHz, Acetone-d_6) 5.80 (1H, d, J=8.1 Hz, pyrimidine-*H*), 6.00 (1H, dq, J=9.7, 9.0 Hz, CF_3CH═CH), 7.18 (1H, d, J=9.7 Hz, CF_3CH═C*H*), 7.50 (1H, d, J=8.1 Hz, pyrimidine-*H*), 10.50 (1H, s, N*H*); *m/z* (EI) 206 (45, M^+), 163 (100%).

4.1.10. 1-[(*E*)-3,3,3-Trifluoro-1-propenyl]-2,4(3*H*)-pyrimidinedione (9b). Mp 157°C; (Found: C, 41.05; H, 2.23; N, 13.60. $C_7H_5F_3N_2O_2$ requires C, 40.78; H, 2.43; N, 13.59%); ν_{max} (Nujol) 3026, 1728, 1677, 1384, 1275, 1135, 1116 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −16.2 (CF_3, d, J=9.2 Hz); δ_H (300 MHz, $CDCl_3$) 5.81–5.91 (1H, m, CF_3CH═CH), 5.93 (1H, d, J=8.2 Hz, pyrimidine-*H*), 7.40 (1H, d, J=8.2 Hz, pyrimidine-*H*), 7.70 (1H, d, J=14.7 Hz, CF_3CH═C*H*); *m/z* (EI) 206 (40, M^+), 163 (100%).

4.1.11. 1-[(*Z*)-3,3,3-Trifluoro-1-propenyl]-5-methyl-2,4(3*H*)-pyrimidinedione (10a). Mp 118°C; (Found: C, 43.52; H, 2.93; N, 12.90. $C_8H_7F_3N_2O_2$ requires C, 43.64; H, 3.18; N, 12.73%); ν_{max} (Nujol) 3181, 3032, 1728, 1674, 1209, 1148, 1109 cm^{-1}; δ_F (56.4 MHz, CD_3COCD_3) −18.5 (CF_3, d, J=9.1 Hz); δ_H (400 MHz, CD_3COCD_3) 1.89 (3H, s, CH_3), 5.89–5.98 (1H, m, CF_3CH═CH), 7.17 (1H, d, J=9.8 Hz, CF_3CH═C*H*), 7.32 (1H, s, thymine-H); *m/z* (EI) 221 (20, M^++1), 220 (56, M^+), 80 (100%).

4.1.12. 1-[(*E*)-3,3,3-Trifluoro-1-propenyl]-5-methyl-2,4(3*H*)-pyrimidinedione (10b). Mp 182°C; (Found: C, 43.80; H, 3.00; N, 12.66. $C_8H_7F_3N_2O_2$ requires C, 43.64; H, 3.18; N, 12.73%); ν_{max} (Nujol) 3194, 3112, 3058, 1713, 1701, 1679, 1657, 1353, 1277, 1131, 1122 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −16.5 (CF_3, d, J=9.0 Hz); δ_H (300 MHz, DMSO-d_6) 1.83 (3H, s, CH_3), 6.42 (1H, m, CF_3CH═CH), 7.65 (1H, d, J=14.8 Hz, CF_3CH═C*H*), 7.96 (1H, s, thymine-H), 11.8 (1H, s, N*H*); *m/z* (EI) 221 (20, M^++1), 220 (61, M^+), 80 (100%).

4.1.13. 2-Bromo-3,3,3-trifluoro-*N*-tosyl-*N*-2-propenyl-1-propanamine (5). To a solution of *N*-propenyl *p*-toluenesulfonamide (**2**) (1.69 g, 8 mmol) and potassium *t*-butoxide (1.24 g, 1.1 mmol) in DMSO (20 mL) and *t*-butyl alcohol (10 mL) was added dropwise 2-bromotrifluoropropene (**1**) (2.1 g, 1.2 mmol.) at room temperature. When the reaction mixture was stirred at room temperature for 1 h and then poured into water (100 mL). The mixture was extracted with ethyl acetate (3×50 mL). The combined extracts was washed with brine and dried over Na_2SO_4. After removal of solvent under reduced pressure, the residue was purified on silica gel column chromatography eluting with ethyl acetate and petroleum ether (1:20) to afford **3a** (1 g, 42%) and **5** (1.2 g, 39%) as colorless oil. **5**: (Found: C, 40.38; H, 3.54; N, 3.71. $C_{13}H_{15}BrF_3NO_2S$ requires C, 40.43; H, 3.91; N, 3.63%); ν_{max} (Nujol) 3015, 1322, 1159, 1115 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −6.28 (CF_3, d, J=7.65 Hz); δ_H (300 MHz, $CDCl_3$) 2.45 (3H, s, CH_3), 3.44 (1H, dd, J=15.5, 9.01 Hz, $CF_3BrHCHa$*Hb*), 3.70 (1H, dd, J=15.5, 4.78 Hz, CF_3BrHC*Ha*Hb), 3.85 (1H, dd, J=15.6, 6.58 Hz, CHa*Hb*CH═CH_2), 3.96 (1H, dd, J=15.6, 6.72 Hz, C*Ha*HbCH═CH_2), 5.14–5.21 (2H, m, CH_2CH═CH_2), 5.52–5.58 (1H, m, $CF_3CBrHCH_2$), 7.35 (2H, d, J=8.41 Hz, 2×Ph-*H*), 7.72 (2H, d, J=8.41 Hz, 2×Ph-*H*); *m/z* (EI) 385 (0.6, M^+), 224 (100), 155 (51), 91 (64%).

4.2. General procedure for synthesis of (*E*)-*N*-[(*Z*)-3,3,3-trifluoropropenyl]-*N*-alkyl-*p*-toluenesulfonamide (3)

Method A: (*Z*)-enamine **3** (0.5 mmol) in decahydronaphthene (2 mL) was heated at 190°C for 30 min, monitored by ^{19}F NMR. After the conversion was completed, decahydronaphthene was removed under reduced pressure. The residue was subjected to flash chromatography on silica gel column eluting with ethyl acetate and petroleum ether (1:15) to afford **4** as colorless oil.

Method B (for **4a**–**d**): (*Z*)-enamine **3a**–**d** (0.5 mmol) in toluene (2 mL) was treated with 40% $BF_3{\cdot}OEt_2$ ether solution (0.05 mmol) at room temperature for 1 h. The mixture was poured into saturated $NaHCO_3$ (10 mL) and extracted with ethyl acetate (3×10 mL). After worked up as usual way, the residue was The residue was subjected to flash chromatography on silica gel column eluting with ethyl acetate and petroleum ether (1:15) to afford **4a**–**d**.

4.2.1. *N*-[(*E*)-3,3,3-Trifluoropropenyl]-*N*-propenyl-*p*-toluenesulfonamide (4a). Colorless oil; (Found: C, 51.20; H, 4.68; N, 4.65. $C_{13}H_{14}F_3NO_2S$ requires C, 51.14; H, 4.59; N, 4.59%); ν_{max} (Nujol) 1688, 1365, 1272, 1169, 1115, 1092 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −17.8 (CF_3, d, J=5.6 Hz); δ_H (300 MHz, $CDCl_3$) 2.44 (3H, s, CH_3), 4.01–4.05 (2H, m, CH_2CH═CH_2), 4.60–4.92 (1H, m, CH_2CH═CH_2), 5.14–5.21 (2H, m, CH_2CH═CH_2), 5.50–5.61 (1H, m, CF_3CH═CH), 7.34 (2H, d, J=8.6 Hz, 2×Ph-*H*), 7.57 (1H, d, J=14.3 Hz, CF_3CH═C*H*), 7.69 (2H, d, J=8.6 Hz, 2×Ph-*H*); *m/z* (EI) 305 (6, M^+), 91 (100%).

4.2.2. *N*-[(*Z*)-3,3,3-Trifluoropropenyl]-*N*-propanyl-*p*-toluenesulfonamide (4b). Colorless oil; (Found: C, 51.04; H,

5.36; N, 4.58. $C_{13}H_{16}F_3NO_2S$ requires C, 50.81; H, 5.21; N, 4.56%); ν_{max} (Nujol) 1668, 1356, 1268, 1175, 1161, 1114, 1088 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −17.8 (CF_3, d, J=6.0 Hz); δ_H (300 MHz, $CDCl_3$) 0.90 (3H, t, J=7.4 Hz, CH_3), 1.58–160 (2H, m, CH_2), 2.44 (3H, s, CH_3), 3.28 (2H, t, J=7.7 Hz, CH_2N), 4.80–4.85 (1H, m, CF_3CH=CH), 7.34 (2H, dd, J=8.5 Hz, Ph-*H*), 7.56 (1H, d, J=14.2 Hz, CF_3CH=C*H*), 7.34 (2H, d, J=8.5 Hz, Ph-*H*); *m/z* (EI) 307 (24, M^+,), 287 (33), 155 (90), 91 (100%).

4.2.3. *N*-[(*E*)-3,3,3-Tifluoropropenyl]-*N*-hexanyl-*p*-toluenesulfonamide (4c). Colorless oil; (Found: C, 54.89; H, 6.47; N, 4.11. $C_{16}H_{22}F_3NO_2S$ requires C, 55.01; H, 6.31; N, 4.01%); ν_{max} (Nujol) 1665, 1357, 1251, 1160, 1126, 1102 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −18.0 (CF_3, d, J=6.0 Hz); δ_H (300 MHz, $CDCl_3$) 0.87 (3H, t, J=6.7 Hz, CH_3), 1.25–1.29 (6H, m, 3×CH_2), 1.51–1.57 (2H, m, CH_2), 2.44 (3H, s, CH_3), 3.30 (2H, t, J=7.7 Hz, CH_2N), 4.77–4.85 (1H, m, CF_3CH=CH), 7.32 (2H, d, J=7.9 Hz, 2×Ph-*H*), 7.54 (1H, d, J=15.0, CF_3CH=C*H*), 7.67 (2H, d, J=8.5 Hz, 2×Ph-*H*); *m/z* (EI) 349 (3, M^+), 265 (69), 155 (85), 91 (100%).

4.2.4. *N*-(*E*)-3,3,3-Trifluoropropenyl]-*N*-phenyl-*p*-toluenesulfonamide (4d). White solid; mp 102°C; (Found: C, 56.13; H, 3.92; N, 3.95. $C_{16}H_{14}F_3NO_2S$ requires C, 56.30; H, 4.11; N, 4.11%); ν_{max} (Nujol) 1667, 1368, 1365, 1170, 1118 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −17.8 (CF_3, d, J=6.0 Hz); δ_H (300 MHz, $CDCl_3$) 2.43 (3H, s), 5.22–5.26 (1H, m, CF_3CH=CH), 7.20–7.27 (5H, m, Ph-*H*), 7.32 (2H, d, J=7.7 Hz, 2×Ph-*H*), 7.60 (1H, d, J=14.2 Hz, CF_3CH=C*H*), 7.62 (2H, d, J=7.7 Hz, 2×Ph-*H*); *m/z* (EI) 341 (8, M^+), 91 (100%).

4.2.5. *N*-[(*E*)-3,3,3-Trifluoropropenyl]-*N*-benzyl-*p*-toluenesulfonamide (4e). White solid; mp 91°C; (Found: C, 57.13; H, 4.37; N, 3.80. $C_{17}H_{16}F_3NO_2S$ requires C, 57.46; H, 4.51; N, 3.94%); ν_{max} (Nujol) 1658, 1373, 1363, 1171 cm^{-1}; δ_F (56.4 MHz, CD_3COCD_3) −17.8. (CF_3, d, J=6.1 Hz); δ_H (300 MHz, CD_3COCD_3) 2.43 (3H, s, CH_3), 4.56 (2H, s, PhCH_2), 4.67–4.74 (1H, m, CF_3CH=CH), 7.16–27 (5H, m, 5×Ph-*H*), 7.30 (2H, d, J=8.3 Hz, 2×Ph-*H*), 7.62 (1H, d, J=14.2 Hz, CF_3CH=C*H*), 7.69 (2H, d, J=8.3 Hz, 2× Ph-*H*); *m/z* (EI) 355 (0.4, M^+), 200 (21), 91 (100%).

4.2.6. *N*-[(*E*)-3,3,3-Trifluoropropenyl]-*N*-[(3-methoxy)-propanyl]-*p*-toluenesulfonamide (4f). Colorless oil; (Found: C, 49.98; H, 5.42; N, 4.03. $C_{14}H_{18}F_3NO_3S$ requires C, 49.85; H, 5.34; N, 4.15%); ν_{max} (Nujol) 1666, 1359, 1266, 1168, 1116 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −18.0 (CF_3, d, J=6.2 Hz); δ_H (300 MHz, $CDCl_3$) 1.81–1.89 (2H, m, CH_2), 2.44 (3H, s, CH_3), 3.30 (3H, s, CH_3O), 3.36 (2H, t, J=5.7 Hz, CH_2), 3.43 (2H, t, J=7.1 Hz, CH_2), 5.00–5.04 (1H, m, CF_3CH=CH), 7.34 (2H, d, J=8.0 Hz, 2×Ph-*H*), 7.55 (1H, d, J=14.3 Hz, CF_3CH=C*H*), 7.68 (2H, d, J=8.0 Hz, 2×Ph-*H*); *m/z* (EI) 337 (2, M^+), 182 (65), 124 (99), 100 (100%).

4.2.7. *N*-[(*E*)-3,3,3-Trifluoropropenyl]-*N*-[1-(3-morpholinyl)propanyl]-*p*-toluenesulfonamide (4g). Colorless oil; (Found: C, 52.11; H, 5.91; N, 7.40. $C_{17}H_{23}F_3N_2O_3S$ requires C, 52.04; H, 5.87; N, 7.14%); ν_{max} (Nujol) 1666, 1357, 1262, 1168, 1118 cm^{-1}; δ_F (56.4 MHz, $CDCl_3$) −18.0 (CF_3, d, J=6.2 Hz); δ_H (300 MHz, $CDCl_3$) 1.71–174 (2H, m, CH_2), 2.37 (2H, t, J=6.5 Hz, CH_2), 2.39 (4H, t, J=4.6 Hz, morpholinyl-*H*), 2.44 (3H, s, CH_3), 3.41 (2H, t, J=7.4 Hz, CH_2N), 3.68 (4H, t, J=4.6 Hz, morpholinyl-*H*), 5.08–5.12 (1H, m, CF_3CH=CH), 7.35 (2H, d, J=8.4 Hz, 2×Ph-*H*), 7.55 (1H, d, J=14.2, Hz, CF_3CH=C*H*), 7.68 (2H, d, J=8.4 Hz, 2×Ph-*H*); *m/z* (EI) 392 (23, M^+), 236 (29), 100 (100%).

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