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Study on the reactions of fluoroalkanesulfonyl azides with indole derivatives

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Abstract

The reactions of fluoroalkanesulfonyl azides **1** with different indole derivatives have been studied in detail. Treatment of **1** with equimolar amount of 1,3-dimethylindole **3** in 1,4-dioxane at room temperature afforded 2-(1,3-dimethyl-1,3-dihydro-indolinylidene) fluoroalkanesulfonylimines **5** in moderate to good yields. However, under the same reaction conditions, in the case of **1** with 1,2-dimethylindole **4**, the corresponding 2-fluoroalkanesulfonyl (1,2-dimethyl-1*H*-indol-3-yl)-amide **6** was obtained in moderate yields. In addition, the reactions of **1** and indole **7** gave different products under different conditions. Possible mechanisms of these reactions were proposed.

Keywords: Fluoroalkanesulfonyl azides; Indole derivatives; 1,3-Dipolar cycloaddition; Triazolines; Diazo transfer

1. Introduction

As an important nucleus of many alkaloids and pigments, indole and its derivatives have achieved an increased significance in medicinal chemistry in recent years [1]. Due to its special structural character, investigations of their chemical transformation also gained much attention [2]. Among them, the reactions of sulfonyl azides with indole and its derivatives were studied extensively. Due to the 1,3-dipolar property of the azide group, they are also readily reacted with many unsaturated compounds, especially with the electron-rich olefins via 1,3-dipolar cycloaddition process.

Bailey et al. had reported the results of their investigations on the reaction of arylsulfonyl azides with indole and alkylindoles [3–5]. For example, 1,3-dimethylindole reacted with arylsulfonyl azides forming 1,3-dimethyl-2-arylsulfonylaminoindoles. The product was different from the material obtained by the reaction of arylsulfonyl azide with 1,2-dimethylindoles. The observed NMR spectra showed that the equilibrium between the tautomers imino and amino form was solvent dependent.

It is well known that replacement of hydrogen by fluorine in biologically active molecules often yields analogues with improved reactivity and selectivity due to the unique physical and chemical properties of fluorine and C–F bond [6]. Per-(or poly) fluroalkanesulfonyl azides $R_fSO_2N_3$ **1** are more reactive than other non-fluorinated organic azides due to the strong electron-withdrawing property of the R_fSO_2 group. Recently, we systematically studied their reactions with electron-rich olefins such as enamines, silyl enol ethers, etc. [7]. As a continuation of our investigation, the reactions of **1** with indole derivatives have been examined in detail. Herein, we report these results and discuss the reaction mechanisms.

2. Results and discussion

Recently, we have reported the reactions of fluoroalkanesulfonyl azides $R_fSO_2N_3$ **1** with *N*-alkylindoles [7e] and found that both solvent and the amount of the azides seriously affected the product distribution (Scheme 1).

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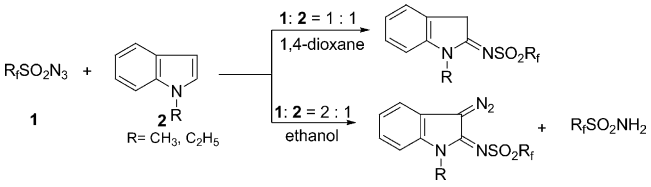
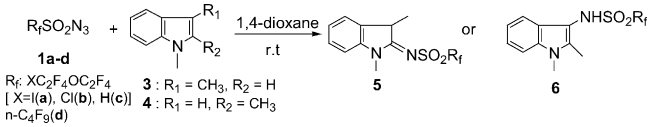


Scheme 1.



Scheme 2.

Based on the previous results, the reaction of fluoroalkanesulfonyl azides with other indole derivatives was further investigated.

The reaction of equimolar fluoroalkanesulfonyl azide **1a** with 1,3-dimethylindole **3** was firstly studied. It proceeded smoothly in anhydrous 1,4-dioxane at room temperature accompanying with nitrogen gas released immediately. TLC analysis showed that the azide **1a** disappeared within 1 h and only one product formed. After the removal of solvent, the residue was separated and purified by column chromatography over silica gel using petroleum ether:ethyl acetate (10:1) as an eluant. The product 2-(1,3-dimethyl-1,3-dihydro-indolinylidene) fluoroalkane sulfonylimines **5a** was isolated in 64% yield and was fully characterized by spectral and elemental analysis. For instance, the MS spectrum of **5a** showed its strong molecular ion peak at *m*/*z* 566. Its ^{1}H NMR consists of four peaks at δ 7.31 (m, 4H), 4.43 (q, 1H), 3.47 (s, 3H), 1.68 (d, 3H), which can be assigned to the corresponding four Ar–H, one benzylic proton at the 3 position, N–CH_3 and 3-CH_3, respectively. Meanwhile, a typical strong absorption at 1567 cm^{-1} in IR spectrum also confirmed the existence of C=N functional group.

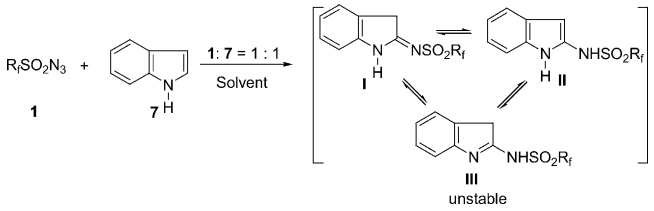
From the previous literature reports [7], we noticed that all the reactions between azides and electron-rich olefins, such as enamine, always afforded the 2-position (close to the heteroatom N) products. So, we assumed that if the 2-position was assembled a group such as methyl group, maybe the migration reaction of 2-methyl group would be happened. However, in the case of fluoroalkanesulfonyl azide **1a** with 1,2-dimethylindole **4** under the same reaction conditions as 1,3-dimethylindole, the expected migration process was not occurred, the reaction system became very complicated and could not obtain one product in pure form during the eluant system (petroleum/ethyl acetate). The same phenomena were also found in the case of fluoroalkanesulfonyl azide **1d**. To our surprise, the reaction was tried successfully by treatment of equimolar amount of fluoroalkanesulfonyl azide **1b** with 1,2-dimethylindole **4**, which afforded a major product **6b** in 34% yield accompanying with several unidentified products in the same eluant system. **6b** was fully characterized by spectral and elemental analysis. For instance, the MS spectrum of **6b** showed its molecular ion peak at *m*/*z* 474. Its ^{1}H NMR consists of four peaks at δ 7.25 (m), 6.57 (br), 3.69 (s), 2.47 (s), which can be assigned to the corresponding four Ar–H, the proton attached to nitrogen atom at the 3 position, the N–CH_3 and the 2-CH_3, respectively. Meanwhile, a typical strong absorption at 3265 cm^{-1} in IR spectrum indicated that the existence of NH functional group. No corresponding strong absorption was observed at about 1500 cm^{-1} in IR spectrum also confirmed the absence of C=N functional group. Thus, the molecular structure of compounds **6b** was determined as 2-fluoroalkanesulfonyl-(1,2-dimethyl-1*H*-indol-3-yl)-amide. Fortunately, when we tried to change the eluant system to petroleum/diethyl ether, the corresponding **6a** and **6d** were obtained in moderate yields. Other azides **1b–d** reacted with **3** or **4** giving similar results (Scheme 2). All these results were summarized in Table 1. It could be found that under the same reaction conditions, the reaction time of **1a** and **1d** with **3** (or **4**) were always shorter than that of **1b** and **1c** (monitored by TLC) (Table 1), these phenomena were also found in our previous studies [7], however, we still could not offer an appropriate explanation to it. Further investigation was under way in our laboratory.

In addition, the reactions of **1** and simple indole and 3-methylindole were also investigated. According to the results of our previous study, the reaction of equimolar amount of simple indole **7** with fluoroalkanesulfonyl azide **1** was studied. It was found that the reaction could proceed smoothly in many solvents such as CH_2Cl_2, Et_2O and 1,4-dioxane. However, whatever solvent was chosen, the color of the reaction system finally turned to blue-black, which resulted in difficult isolating the expected sulfonylimines in pure form, though the product could be detected from the TLC analysis. From the results obtained by the following ^{19}F NMR spectra, we found that the solvents affected the product distribution significantly. For example, in the first 3 min the conversion yields of **1a** were 3, 20, and 31% in the corresponding CH_2Cl_2, Et_2O and 1,4-dioxane, respectively. However, in the case of ethanol, the conversion yield of **1a**

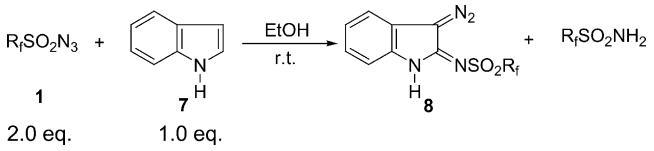
Table 1
Reaction results of fluoroalkanesulfonyl azides **1** with indole derivatives

Entry	Azides	Indoles **3** or **4**	Time (h)	Products **5** or **6**	Yields (%)[a,b]
1	**1a**	**3**	1	**5a**	64 (85)
2	**1b**	**3**	2	**5b**	75 (92)
3	**1c**	**3**	2	**5c**	78 (94)
4	**1d**	**3**	1	**5d**	87 (97)
5	**1a**	**4**	2	**6a**[c]	67 (85)
6	**1b**	**4**	4	**6b**	34 (80)
7	**1c**	**4**	4	**6c**	26 (77)
8	**1d**	**4**	2	**6d**[c]	66 (87)

[a] Isolated yields.
[b] The yields in bracket are determined by ^{19}F NMR spectra when the reaction finished.
[c] **6a** and **6d** are separated by eluant system of petroleum/Et_2O.



Scheme 3.

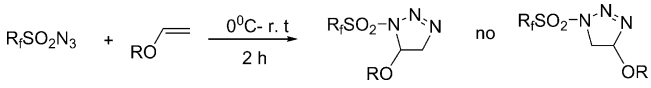


Scheme 4.

Table 2
Reaction results of fluoroalkanesulfonyl azides with simple indole

Entry	Azides	T (°C)	Conditions[a], molar ratio (1/7)	Products	Yields (%)[b]
1	**1a**	20	2	**8a**	79
2	**1b**	20	2	**8b**	63
3	**1c**	20	2	**8c**	67
4	**1d**	20	2	**8d**	51

[a] All reaction finished within 5 min.
[b] Isolated yields.



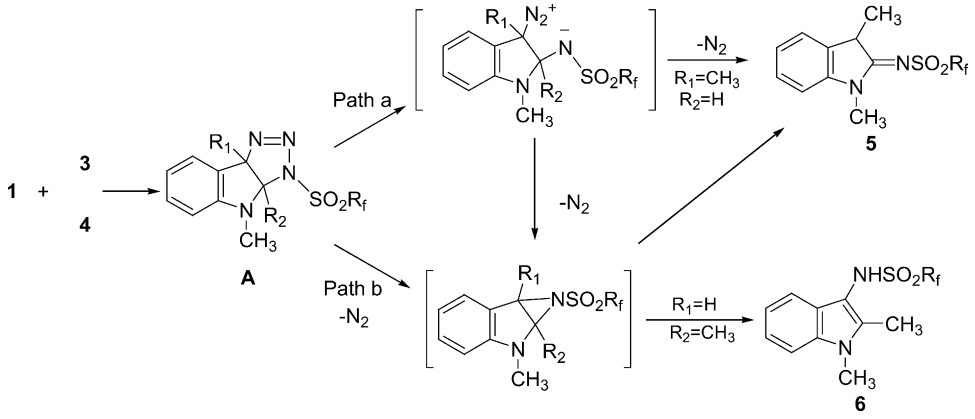
Scheme 5.

was up to 96%, three products of sulfonylimine, diazo compounds and sulfonylamide were formed in almost equal ratio (32:31:37). As we reported in early studies, the same phenomena were also appeared in the case of simple indole, i.e., 1,4-dioxane is the suitable solvent for the formation of the corresponding sulfonylimines, and the strong polar and protonic solvent ethanol favored the formation of diazo product **8**. Comparing with the results of non-fluorianted sulfonyl azide with simple indole, the above results may be explained well by the following factors: (1) the active proton in indole molecule resulted in the possibility of the quick equilibrium between structure I, II and III once one structure was formed (Scheme 3). This point can be detected during the isolation process, two products (R_f is 0.1 and 0.5 in $V_{petroleum}/V_{ethyl\ acetate}$, 10:1) were obtained in the meantime, whatever eluant we selected. (2) The more reactive fluoroalkanesulfonyl azides resulted in the fast formation of sulfonylimine and the resulted sulfonylimines was unstable, this point can be confirmed by the following studies.

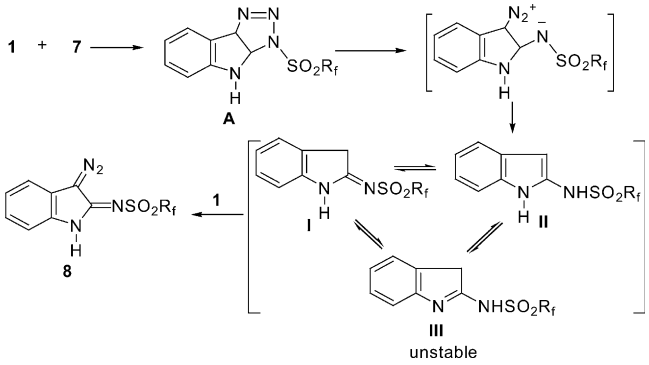
Encouraged by the above results and previous studies [7e], the reaction of two equimolar amounts of fluoroalkanesulfonyl azides **1a** with indole **7** was performed in anhydrous ethanol at room temperature. It was found that the reaction proceeded smoothly and completed within 5 min. The product **8a** was separated in good yields accompanying with the corresponding fluoroalkanesulfonylamine $R_fSO_2NH_2$ (Scheme 4). According to our previous results, **8a** was easily identified as *N*-unsubstituted-2-fluoroalkanesulfonimino-3-diazo-indolines. Other azides **1b–d** reacted with 2 equiv. amount of indole in ethanol affording similar results, which were summarized in Table 2.

Under the optimal solvent and the molar ratio of substrates, 3-methylindole **9** was also applied to these reaction protocols. However, when 3-methylindole **9** was used to react with equimolar amount of **1**, in 1,4-dioxane at room temperature, no reaction occurred within 3 days. Increasing the temperature to reflux the reaction system became complicated. Treatment of 2.0 equimolar amount of fluoroalkanesulfonyl azide with **9** in anhydrous ethanol at room temperature, it proceeded smoothly and yielded at least five products and could not be isolated successfully, which may be due to the more reactive properties of fluoroalkanesulfonyl azides than non-fluorinated azides.

In our previous study on the fluoroalkanesulfonyl azides **1**, the nitrene intermediates R_fSO_2N formed thermally at 110 °C. Therefore, in above reaction condition (room temperature) the nitrene intermediates should not be



Scheme 6. Possible mechanism for the formation of products **5** and **6**.



Scheme 7. Possible mechanism for the formation of **8**.

involved. In addition, we also noticed that the initial 1,3-dipolar cycloaddition process of fluoroalkanesulfonyl azides with electron-rich alkenes was regiospecific. For example, the reaction of fluoroalkanesulfonyl azides with vinyl ethers afforded 1-fluoroalkanesulfonyl 5-alkoxy-1,2,3-triazoles regiospecifically (Scheme 5) [7d].

Thus, we proposed that in the reactions of azides **1** with indole derivatives (**3**, **4**, **7**), the triazoline **A** should be formed regiospecifically firstly (Scheme 6). It is well known that the triazoline ring carrying an electron-withdrawing group at the 1-position is very labile [8–9]. The triazolines **A** thus decomposed immediately followed by an elimination of N_2 gas, and then either by 1,2-H shift or from aziridines intermediates affording the product amidines **5** (path a). The formation of product **6** may be from aziridines intermediate (path b).

According to the mechanism proposed in the case of *N*-alkyl indoles [7e], the transfer of diazo group from sulfonyl azides was supposed to involve a carbanion as the reactive species. Thus, in the case of indole **7**, albeit the intermediates (**I–III**) involved were unstable and could not be separated solely, a similar possible formation of diazo compounds **8** may be proposed (Scheme 7).

3. Conclusions

In summary, the reactions of fluoroalkanesulfonyl azides with several indole derivatives under mild reaction condition were studied in detail. Treated **1** with equimolar amount of 1,3-dimethylindole **3** in 1,4-dioxane at room temperature affording 2-(1,3-dimethyl-1,3-dihydro-indolinylidene) fluoroalkane sulfonylimines **5** in moderate to good yields. However, in the case of **1** with 1,2-dimethylindole **4**, under the same reaction conditions, the corresponding 2-fluoroalkanesulfonyl (1,2-dimethyl-1*H*-indol-3-yl)-amide **6** were obtained in moderate yields. In addition, the treatment of simple indole **7** with 2.0 equiv. of **1** in ethanol afforded *N*-unsubstituted-2-fluoroalkanesulfonimino-3-diazo-indolines **4** in good yields. The obtained products are important synthons in many synthesis processes, their chemical transformations are under way in our lab.

4. Experimental

Melting points were measured in Temp-Melt apparatus and were uncorrected. ^{1}H and ^{19}F NMR spectra were recorded in $CDCl_3$ (unless mentioned in text), Bruker AM-300 instruments with Me_4Si and $CFCl_3$ (with upfield negative) as the internal and external standards, respectively. IR spectra were obtained with a Nicolet AV-360 spectrophotometer. Lower resolution mass spectrum or high-resolution mass spectra (HRMS) were obtained on a Finnigan GC-MS 4021 or a Finnigan MAT-8430 instrument using the electron impact ionization technique (70 eV), respectively (unless mentioned in text). Elemental analyses were performed by this Institute. All solvents were purified before use. Fluoroalkanesulfonyl azides **1** and indoles derivatives were prepared according to literature [10–11].

4.1. Typical procedure for the preparation of 2-(1,3-dimethyl-1,3-dihydro-indolinylidene) fluoroalkane sulfonylimines ***5***

To a 10-mL round-bottom flask containing 1,3-dimethylindoles **3** (1.0 equiv.) in 2 mL 1,4-dioxane was added slowly fluoroalkanesulfonyl azides **1a** (1.0 equiv.) at room temperature within 2 min. Then the mixture was continuously stirred at room temperature within 1 h until TLC analysis shown the reaction finished. The solvent was evaporated and the residue was chromatographed on a silica column using petroleum ether:ethyl acetate (10:1) as eluant to give pure product **5a** as a white solid.

4.1.1. 2-(1,3-Dimethyl-indolinylidene)-(5′-iodo-3′-oxa-octafluoropentyl)-sulfonylimines ***5a***

White solid, m.p. 87–89 °C. FT-IR (ν_{max}, cm^{-1}): 1567, 1499, 1318, 1174, 955. ^{1}H NMR δ (ppm): 7.41–7.09 (m, 4H, ArH), 4.43 (q, J = 6.9 Hz, 1H, CH), 3.47 (s, 3H, NCH_3), 1.68 (d, J = 7.2 Hz, 3H, $CHCH_3$). ^{19}F NMR δ (ppm): −64.99 (t, J = 5.92 Hz, 2F, ICF_2), −81.25 (m, 2F, CF_2O), −85.73 (m, 2F, OCF_2), −116.89 (s, 2F, CF_2S). MS *m/z* (ion, %): 566 (M^+, 25), 227 ($IC_2F_4^+$, 10), 159 ($M^+-R_fSO_2$, 100), 144 ($M^+-R_fSO_2NH$, 35). Anal. calcd. for $C_{14}H_{11}F_8IN_2O_3S$: C, 29.68; H, 1.94; N, 4.95; found: C, 29.76; H, 2.14; N, 4.89.

4.1.2. 2-(1,3-Dimethyl-indolinylidene)-(5′-chloro-3′-oxa-octafluoropentyl)-sulfonylimines ***5b***

White solid, m.p. 94–96 °C. FT-IR (ν_{max}, cm^{-1}): 1568, 1500, 1322, 1171, 1139, 966. ^{1}H NMR δ (ppm): 7.42–7.09 (m, 4H, ArH), 4.43 (q, J = 7.5 Hz, 1H, CH), 3.47 (s, 3H, NCH_3), 1.68 (d, J = 7.2 Hz, 3H, $CHCH_3$). ^{19}F NMR δ (ppm): −73.98 (s, 2F, $ClCF_2$), −81.26 (t, J = 13Hz, 2F, CF_2O), −87.02 (t, J = 13Hz, 2F, OCF_2), −116.96 (s, 2F, CF_2S). MS *m/z* (ion, %): 476/474 (M^+, 7/18), 159 ($M^+-R_fSO_2$, 100), 144 ($M^+-R_fSO_2NH$, 31). Anal. calcd. for $C_{14}H_{11}ClF_8N_2O_3S$: C, 35.44; H, 2.32; N, 5.91; found: C, 35.82; H, 2.47; N, 5.80.

4.1.3. 2-(1,3-Dimethyl-indolinylidene)-(1′,1′,2′,2′,4′,4′,5′,5′-octafluoro-3′-oxa-pentyl)sulfonylimines ***5c***

White solid, m.p. 98–100 °C. FT-IR (ν_{max}, cm^{-1}): 1563, 1499, 1327, 1167, 1143, 952. ^1H NMR δ (ppm): 7.44–7.10 (m, 4H, ArH), 5.87 (t-t, J = 3.0, 52.5 Hz, 1H, HCF_2), 4.42 (q, J = 7.8 Hz, 1H, CH), 3.48 (s, 3H, NCH_3), 1.68 (d, J = 7.8 Hz, 3H, $CHCH_3$). ^{19}F NMR δ (ppm): −80.93 (t, J = 12 Hz, 2F, CF_2), −88.80 (m, 2F, CF_2O), −117.11 (s, 2F, OCF_2), −137.63 (d, J = 53.4Hz, 2F, HCF_2). MS *m/z* (ion, %): 440 (M^+, 27), 159 ($M^+-R_fSO_2$, 100), 144 ($M^+-R_fSO_2NH$, 37). Anal. calcd. for $C_{14}H_{12}F_8N_2O_3S$: C, 38.18; H, 2.73; N, 6.36; found: C, 38.49; H, 2.77; N, 6.35.

4.1.4. 2-(1,3-Dimethyl-indolinylidene)-perfluorobutylsulfonylimines ***5d***

White solid, m.p. 111–113 °C. FT-IR (ν_{max}, cm^{-1}): 1569, 1499, 1328, 1165, 1138, 961. ^1H NMR δ (ppm): 7.45–7.11 (m, 4H, ArH), 4.44 (q, J = 7.6 Hz, 1H, CH), 3.48 (s, 3H, NCH_3), 1.69 (d, J = 7.5 Hz, 3H, $CHCH_3$). ^{19}F NMR δ (ppm): −80.98 (m, 3F, CF_3), −113.53 (m, 2F, CF_2S), −120.97 (s, 2F, CF_2), −126.15 (m, 2F, CF_3CF_2). MS *m/z* (ion, %): 442 (M^+, 30), 159 ($M^+-R_fSO_2$, 100), 144 ($M^+-R_fSO_2NH$, 44). Anal. calcd. for $C_{14}H_{11}F_9N_2O_2S$: C, 38.01; H, 2.49; N, 6.33; found: C, 38.16; H, 2.61; N, 6.05.

4.2. Typical procedure for the preparation of 2-fluoroalkanesulfonyl (1,2-dimethyl-1H-indol-3-yl)-amide ***6***

To a 10-mL round-bottom flask containing 1,2-dimethylindoles **4** (1.0 equiv.) in 2 mL 1,4-dioxane was added slowly fluoroalkanesulfonyl azides **1b** (1.0 equiv.) at room temperature within 2 min. Then the mixture was continuously stirred at room temperature within 4 h until TLC analysis shown the reaction finished. The solvent was evaporated and the residue was chromatographed on a silica column using petroleum ether:ethyl acetate (10:1) as eluant to give pure product **6b** as a carmine solid. To **6a** and **6d**, the petroleum ether:ethyl ether (4:1) was selected.

4.2.1. 2-(5′-Iodo-3′-oxa-octafluoropentyl)sulfonyl-(1,2-dimethyl-1H-indol-3-yl)-amide ***6a***

Carmine solid, m.p. 100–102 °C. FT-IR (ν_{max}, cm^{-1}): 3266, 2963, 1413, 1333, 1262, 1153, 1093, 917. ^1H NMR δ (ppm): 7.54–7.16 (m, 4H, ArH), 6.53 (br, 1H, NH), 3.67 (s, 3H, NCH_3), 2.45 (s, 3H, 2-CH_3). ^{19}F NMR δ (ppm): −65.29 (t, J = 5.9 Hz, 2F, ICF_2), −81.84 (t, J = 13 Hz, 2F, CF_2O), −85.87 (m, 2F, OCF_2), −115.59 (s, 2F, CF_2S). MS *m/z* (ion, %): 566 (M^+, 1), 159 ($M^+-R_fSO_2$, 100). Anal. calcd. for $C_{14}H_{11}F_8IN_2O_3S$: C, 29.68; H, 1.94; N, 4.95; found: C, 29.29; H, 2.08; N, 4.71.

4.2.2. 2- (5′-Chloro-3′-oxa-octafluoropentyl) sulfonyl-(1,2-dimethyl-1H-indol-3-yl)-amide ***6b***

Carmine solid, m.p. 116–118 °C. FT-IR (ν_{max}, cm^{-1}): 3265, 2925, 2858, 1411, 1345, 1211, 1148, 975. ^1H NMR δ (ppm): 7.55–7.16 (m, 4H, ArH), 6.57 (br, 1H, NH), 3.69 (s, 3H, NCH_3), 2.47 (s, 3H, 2-CH_3). ^{19}F NMR δ (ppm): −73.97 (2F, s, $ClCF_2$), −81.66 (t, J = 12 Hz, 2F, CF_2O), −120.97 (t, J = 12 Hz, 2F, OCF_2), −115.48 (m, 2F, CF_2S). MS *m/z* (ion, %): 476/474 (M^+, 1.5/4), 159 ($M^+-R_fSO_2$, 100). Anal. calcd. for $C_{14}H_{11}ClF_8N_2O_3S$: C, 35.41; H, 2.32; N, 5.90; found: C, 35.53; H, 2.34; N, 5.88.

4.2.3. 2-(1′,1′,2′,2′,4′,4′,5′,5′-Octafluoro-3′-oxa-pentyl)sulfonyl (1,2-dimethyl-1H-indol-3-yl)-amide ***6c***

Carmine solid, m.p. 112–114 °C. FT-IR (ν_{max}, cm^{-1}): 3273, 2924, 2869, 1410, 1329, 1210, 1163, 857. ^1H NMR δ (ppm): 7.55–7.16 (m, 4H, ArH), 6.53 (br, 1H, NH) 5.78 (t-t, J = 3.0, 49 Hz, 1H, HCF_2), 3.70 (s, 3H, NCH_3), 2.47 (s, 3H, 2-CH_3). ^{19}F NMR δ (ppm): −81.38 (t, J = 13Hz, 2F, OCF_2), −88.79 (m, 2F, CF_2O), −115.47 (m, 2F, SCF_2), −137.60 (d, J = 53Hz, 2F, HCF_2). MS *m/z* (ion, %): 440 (M^+, 6), 159 ($M^+-R_fSO_2$, 100). Anal. calcd. for $C_{14}H_{12}F_8N_2O_3S$: C, 38.18; H, 2.73; N, 6.36; found: C, 38.20; H, 2.85; N, 6.34.

4.2.4. Perfluorobutylsulfonyl-(1,2-dimethyl-1H-indol-3-yl) -amide ***6d***

Carmine solid, m.p. 92–94 °C. FT-IR (ν_{max}, cm^{-1}): 3294, 2962, 1409, 1352, 1226, 1192, 1143, 1033. ^1H NMR δ (ppm): 7.52–7.16 (m, 4H, ArH), 6.65 (br, 1H, NH), 3.68 (s, 3H, NCH_3), 2.45 (s, 3H, 2-CH_3). ^{19}F NMR δ (ppm): −81.12 (t, J = 9.3 Hz, 3F, CF_3), −112.06 (t, J = 12 Hz, 2F, CF_2S), −121.26 (t, J = 3.4 Hz, 2F, CF_2), −126.39 (m, 2F, CF_2). MS *m/z* (ion, %): 442 (M^+, 4), 159 ($M^+-R_fSO_2$, 100). HRMS (MALDI) for $C_{14}H_{12}F_9N_2O_2S$ $[M^+H]^+$ calcd.: 443.04496; found: 443.04703.

4.3. Typical procedure for the preparation of N-unsubstituted-2-fluoroalkanesulfonimino-3-diazo-indolines ***8***

To a 10-mL round-bottom flask containing simple indoles **7** (1.0 equiv.) in 2 mL anhydrous ethanol was added slowly fluoroalkanesulfonyl azides **1a** (2.0 equiv.) at room temperature within 2 min. Then the mixture was continuously stirred at r.t. within 5 min until TLC analysis shown the reaction finished. The solvent was evaporated and the residue was chromatographed on a silica column using petroleum ether:ethyl acetate (4:1) as eluant to give pure product **8a** as a yellowish solid.

4.3.1. 2-(5′-Iodo-3′-oxa-octafluoropentyl)-sulfonimino-3-diazo-indolines ***8a***

Yellow solid, m.p. 122–124 °C. FT-IR (ν_{max}, cm^{-1}): 3331, 2924, 2136 (s, C=N^+=N^-), 1568 (s, C=N), 1327, 1156, 913. ^1H NMR δ (ppm): 10.02 (br, 1H, NH), 7.41–7.27 (m, 4H, ArH). ^{19}F NMR δ (ppm): −65.03 (s, 2F, ICF_2), −81.72 (s, 2F, CF_2O), −85.62 (m, 2F, OCF_2), −116.88 (s, 2F, CF_2S). MS *m/z* (ion, %): 564 (M^+, 22), 227 ($IC_2F_4^+$, 23), 221 (M^+-R_f, 47), 193 ($M^+-R_f-N_2$, 20), 145 ($M^+-R_fSO_2N$,

47), 102 ($C_8H_6^+$, 100). Anal. calcd. for $C_{12}H_5F_8IN_4O_3S$: C, 25.53; H, 0.89; N, 9.93; found: C, 25.67; H, 1.13; N, 10.22.

4.3.2. 2-(5′-Chloro-3′-oxa-octafluoropentyl)-sulfonimino-3-diazo-indolines ***8b***

Yellow solid, m.p. 147–149 °C. FT-IR (ν_{max}, cm^{-1}): 3298, 2156 (s, C=N^+=N^-), 1547 (s, C=N), 1389, 1341, 1303, 1175, 1132, 1007. ^{1}H NMR δ (ppm): 9.91 (br, 1H, NH), 7.42–7.22 (m, 4H, ArH). ^{19}F NMR δ (ppm): −74.15 (s, 2F, $ClCF_2$), −81.89 (t, 2F, J = 13.4 Hz, CF_2O), −87.14 (t, 2F, J = 12.7 Hz, OCF_2), −117.18 (s, 2F, CF_2S). MS m/z (ion, %): 474/472 (M^+, 4/10), 221 (M^+-R_f, 47), 193 ($M^+-R_f-N_2$, 20), 166 ($M^+-R_f-N_2$–HCN, 96), 145 ($M^+-R_fSO_2N$, 47), 102 ($C_8H_6^+$, 100). Anal. calcd. for $C_{12}H_5ClF_8N_4O_3S$: C, 30.48; H, 1.06; N, 11.85; found: C, 30.25; H, 1.13; N, 11.64.

4.3.3. 2-(1′,1′,2′,2′,4′,4′,5′,5′-Octafluoro-3′-oxa-pentyl)-sulfonimino-3-diazo-indolines ***8c***

Yellow solid, m.p. 152–154 °C. FT-IR (ν_{max}, cm^{-1}): 3379, 2141 (s, C=N^+=N^-), 1575 (s, C=N), 1463, 1410, 1048, 1015, 898, 837. ^{1}H NMR δ (ppm): 10.10 (br, 1H, NH), 7.40–7.26 (m, 4H, ArH), 5.86 (t-t, J = 3.0 Hz, 49.5 Hz, 1H, HCF_2). ^{19}F NMR δ (ppm): −81.64 (m, 2F, CF_2), −88.81 (m, 2F, CF_2O), −117.07 (s, 2F, CF_2S), −137.79 (d, J = 53.9 Hz, 2F, HCF_2). MS m/z (ion, %): 438 (M^+, 16), 221 (M^+-R_f, 34), 193 ($M^+-R_f-N_2$, 45), 166 ($M^+-R_f-N_2$–HCN, 100), 145 ($M^+-R_fSO_2N$, 39), 102 ($C_8H_6^+$, 64), HRMS for $C_{12}H_6F_8N_4O_3S$ calcd.: 438.00329; found: 438.00128.

4.3.4. 2-Perfluorobutylsulfonimino-3-diazo-indolines ***8d***

Yellow solid, m.p. 173–175 °C. FT-IR (ν_{max}, cm^{-1}): 3230, 2960, 2146 (s, C=N^+=N^-), 1393 (s, C=N), 1349, 1251, 1199, 1158, 1132, 1051. ^{1}H NMR δ (ppm): 9.96 (br, 1H, NH), 7.42–7.26 (m, 4H, ArH). ^{19}F NMR δ (ppm): −81.14 (t, J = 9.9 Hz, 3F, CF_3), −113.65 (t, J = 13.8 Hz, 2F, CF_2), −121.55 (m, 2F, CF_2), −126.31 (m, 2F, CF_2S). MS m/z (ion, %): 440 (M^+, 22), 221 (M^+-R_f, 39), 193 ($M^+-R_f-N_2$, 40), 166 ($M^+-R_f-N_2$–HCN, 100), 145 ($M^+-R_fSO_2N$, 45), 102 ($C_8H_6^+$, 72). Anal. calcd. for $C_{12}H_5F_9N_4O_3S$: C, 32.73; H, 1.14; N, 12.73; found: C, 33.07; H, 1.24; N, 12.45.

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