One-pot Preparation of Fluorinated Polyhydrobenzoacridine-1-one Derivatives under Microwave Irradiation and Solvent-free Conditions

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A facile and efficient synthesis of fluorine-containing polyhydrobenzoacridines was accomplished by a three-component coupling of fluorinated aldehyde, α-naphthylamine, and 1,3-cyclohexanedione or dimedone under microwave irradiation and solvent-free conditions without catalyst. All new compounds were obtained in moderate to good yields and characterized by standard spectroscopic methods.

Keywords fluorinated polyhydrobenzoacridines, condensation reaction, microwave irradiation, one-pot, three-component coupling

Introduction

The acridine derivatives have been known first to be used as pigments and dyes.[1] Then they are considered to be important chemotherapeutics for the bactericidal and antimalarial activities.[2] In addition, polyhydroacridine derivatives have high fluorescence efficiency and have been reported to be used as fluorescent molecular probes for monitoring of polymerization process.[3] They are also increasingly receiving attention due to their likeness in properties with those of 1,4-dihydropyridines, which have similarities in structure to the biologically important compounds such as NADH and NADPH.[4] As a consequence, the interest of organic chemists in the synthesis or structure modifications of acridinedione derivatives remains high.

Recently, microwave-promoted reactions, especially those run in water or solvent-free conditions have been attracting increasing research interest from chemists, not only because these reactions exhibit some particular or unexpected reactivities in some cases but also because they are significantly useful for green chemistry.[5] Meanwhile, a one-pot multi-component reaction (MCR), as a versatile strategy in organic synthesis, has been caught much attention. In our corresponding investigations, we have reported a series of microwave-promoted synthesis, such as 2-pentafluorophenylquinoline derivatives,[6] α-aminoalkyl phosphonates[7] and fluorinated propargylamines,[8] *etc.*

Furthermore, the three-component coupling of aldehyde, amine and diketone (A^3 coupling) transformed to polyhydrobenzoacridines can be finished by microwave irradiation.[9] To our best knowledge, the preparation of poly- or perfluorinated polyhydrobenzoacridines has not been reported.

As a part of our current work connected the microwave-promoted reactions with the organofluorine chemistry, we describe an efficient and clean one-pot procedure for the preparation of fluorinated polyhydrobenzoacridines under microwave irradiation and solvent-free conditions without catalyst.

Results and discussion

The microwave-promoted three-component coupling experiment was performed by irradiation of a mixture with equimolecular amounts of fluorinated benzoaldehyde, α-naphthylamine, and diketone in a flask under solvent-free conditions without catalyst to afford the desired 9-fluorinated phenyl substituted 1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one derivates (Table 1).

The chemical synthesis procedure was easy to operate. Compared with the traditional heating methodology which was carried out in the C_6H_6, EtOH, or H_2O for several hours, in our case, the reaction time was shortened to several minutes, and without any catalyst and solvent. In a word, this synthetic method was fit for the philosophy of green chemistry.

All the new products were fully characterized by IR, ^{1}H NMR, ^{19}F NMR, MS and elemental analysis. For

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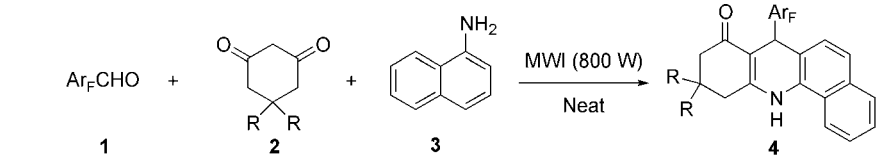
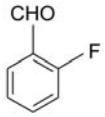
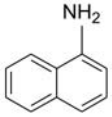
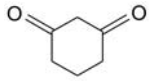
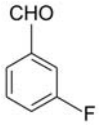
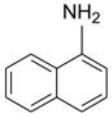
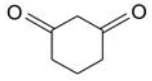
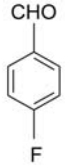
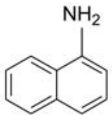
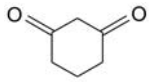
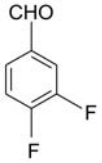
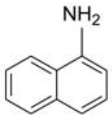
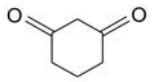
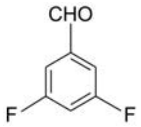
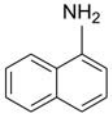
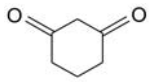
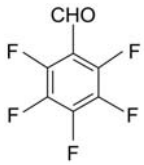
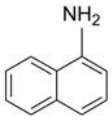
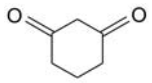
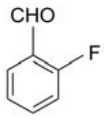
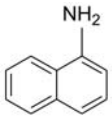
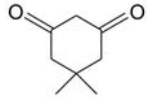
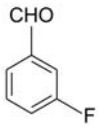
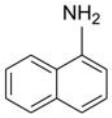
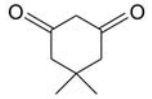
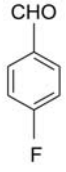
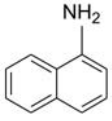
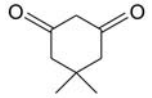
Table 1 Synthesis of the fluorinated polyhydrobenzoacridines



1 **2** **3** **4**

1a Ar_F = *o*-FC_6H_4
1b Ar_F = *m*-FC_6H_4
1c Ar_F = *p*-FC_6H_4
1d Ar_F = *p,m*-$F_2C_6H_3$
1e Ar_F = *m,m*-$F_2C_6H_3$
1f Ar_F = C_6F_5

2a R = H
2b R = CH_3

Entry	Aldehyde (**1**)	α-Naphthylamine (**2**)	Diketone (**3**)	Product (**4**)	Time/min	Yield/%
1				**4aa**	8	59
2				**4ba**	6	68
3				**4ca**	5	76
4				**4da**	5	74
5				**4ea**	6	83
6				**4fa**	8	51
7				**4ab**	7	64
8				**4bb**	6	71
9				**4cb**	5	79

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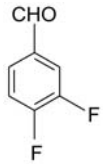
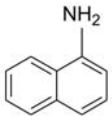
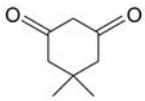
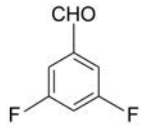
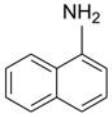
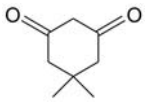
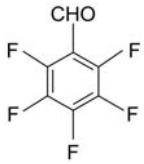
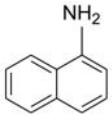
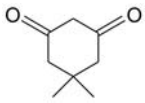
Entry	Aldehyde (**1**)	α-Naphthylamine (**2**)	Diketone (**3**)	Product (**4**)	Time/min	Yield/%
10				**4db**	6	81
11				**4eb**	5	75
12				**4fb**	8	48

example, the FT-IR of **4aa** spectrum showed single acutely middle intension signal at about 3307 cm^{-1} for the vibration of NH, and a strong band at 1587 cm^{-1} for its carbonyl group. Its ^1H NMR spectrum appeared multiplet at δ 2.97—1.92 for three CH_2 protons, a singlet at δ 5.54 for C(7)-H, multiplet in the region δ 7.00—7.59 for aromatic protons, doublet at δ 7.80, 8.47 for C(9)-H, C(10)-H, and a singlet at δ 9.35 for NH proton. The ^{19}F NMR spectrum was very similar to the starting fluorinated aldehyde, showed multiplet at δ −118.73 for a fluorine atom. The mass spectrum exhibited a molecular ion peak at *m/z* 343 ($[M]^+$) and its base peak at *m/z* 248 ($[M-FC_6H_4]^+$). The spectra of compounds **4ab**—**4fb** were similar to the compounds **4aa**—**4fa** except another two singlets at about δ 1.00 for two CH_3 protons.

The molecular structure of **4cb** was further determined by X-ray crystal diffraction analysis. Its molecular structure and the packing map are shown in Figure 1. The selected bond lengths (Å) and bond angles (°) for compound **4cb** are listed in Table 1. This compound showed strong intermolecular hydrogen bonding between N—H···O ($d_{N-H\cdots O}$=2.127 Å; ∠N—H···O=163.23°), and the weak intermolecular hydrogen bonding between C—H···F ($d_{C-H\cdots F}$=2.666 Å; ∠C—H···F=165.29°) and C—H···O ($d_{C-H\cdots O}$=2.436 Å; ∠C—H···O=168.44°) (Figure 2).

On the basis of the experimental results above, together with some literature reports,[10] two tentative reaction pathways are proposed as shown in Scheme 1. In path a, fluorinated benzoaldehyde **1** reacted with diketone **2** to form intermediate **A**, which was attacked by α-naphthylamine **3** to the C=C double bond and transformed to **B**. Finally, the target product **4** was obtained after losing H_2O. Another pathway was that α-naphthylamine **3** attacked the carbonyl group of **A** to give intermediate **C**. Then the product **4** was obtained after electrocyclic reaction and followed by a [1,3]-H-shift.

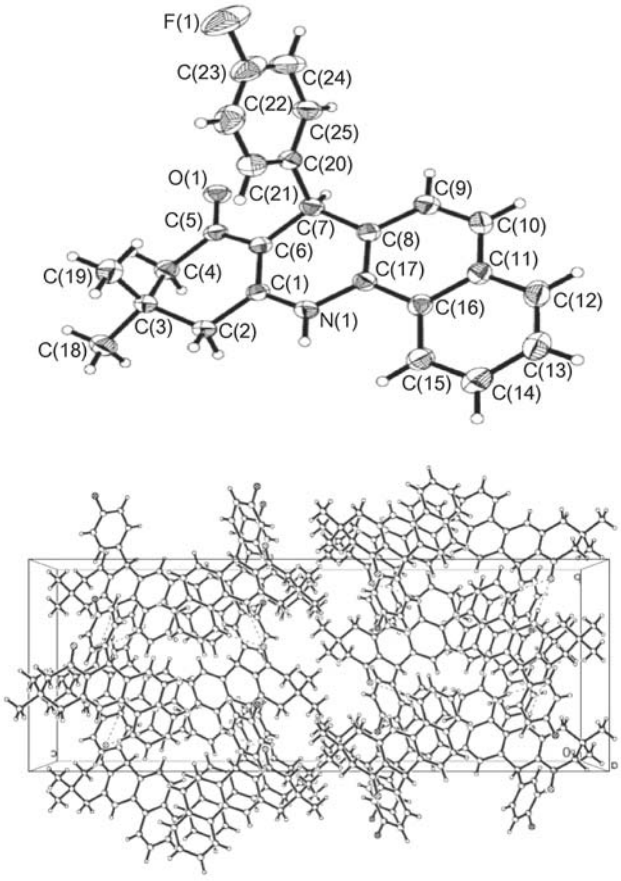


Figure 1 Crystal structure and the packing map of compound **4cb**.

Conclusion

In summary, we have developed an efficient green three-component reaction for the preparation of poly- and perfluorinated polyhydrobenzoacridines under microwave irradiation and solvent-free conditions. The notable advantages of this procedure, such as environ-

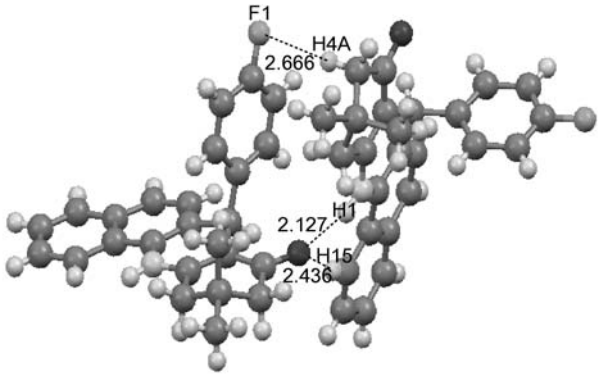


Figure 2 The intermolecular hydrogen bonds of compound **4cb**.

mental friendly, simple workup procedure, short route and reaction time, make this method attractive and useful in synthesis fields. Further chemical transformation and the potential performances of these products are still under investigation in our laboratory.

Experimental

General experimental techniques and apparatus

All reactions were performed in an improved domestic Sanyo, EM-551S/550S, microwave oven (2450 MHz, 80—800 W). TLC was performed on precoated silica gel F-254 plates (0.25 mm; E. Merck), and product(s) and starting material(s) were detected by viewing under UV light. Column chromatography was performed on silica gel (200—300 mesh). Melting points were determined in open capillaries and were uncorrected. Infrared spectra were recorded on an AVATAR370 FT spectrophotometer (Perkin Elmer, USA). NMR spectra were determined with DRX500MHz spectrometer (Bruker, Germany), using solutions in deuterated dimethylsulfoxide with Me_4Si and $CFCl_3$ as the internal and external standards for ^1H and ^{19}F nuclei, respectively. Low resolution mass spectrum was obtained on Finnigan GC-MS 4021 instrument using the electron impact ionization technique (70 eV). Elemental analyses were performed in this Institute. X-ray diffraction crystal structure analysis was obtained on Bruker SMART P4 instrument.

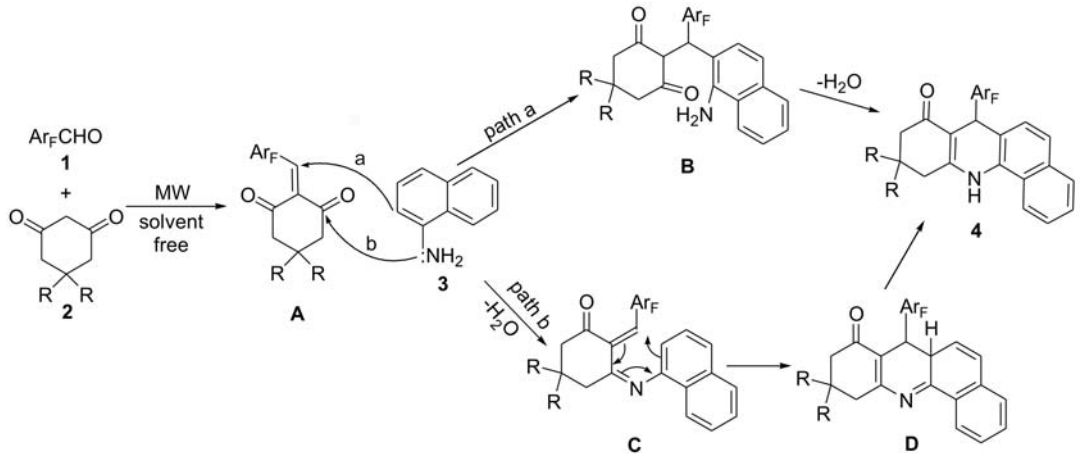
Synthesis of polyhydrobenzoacridines

Fluorinated benzoaldehyde (2 mmol), α-naphthylamine (2 mmol), 1,3-cyclohexanedione or dimedone (2 mmol) were mixed and put into a 50 mL flask, then it was exposed to microwave irradiation at 800 W using a microwave oven for an appropriate time as checked by TLC (Table 2). After completion of the reaction, the reaction mixture was diluted with water. Then the precipitate formed and filtered to obtain the crude material, which was further purified by flash column chromatography [using *V*(petroleum ether)∶*V*(ethylacetate)=4∶1 as eluant] to afford pure products.

3,3-Dihydro-9-(2-fluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4aa) Yellow solid; m.p. 258—259 ℃; ^1H NMR (DMSO-d_6, 500 MHz) δ: 9.35 (s, 1H, NH), 8.47 (d, J=8.5 Hz, 1H, ArH), 7.80 (d, J=8.0 Hz, 1H, ArH), 7.59—7.44 (m, 3H, ArH), 7.24—7.21 (m, 2H, ArH), 7.12—7.00 (m, 3H, ArH), 5.54 (s, 1H, CH), 2.97—2.92 (m, 1H, CH), 2.77—2.70 (m, 1H, CH), 2.30—2.20 (m, 2H, CH_2), 2.04—1.92 (m, 2H, CH_2); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −118.70—−118.75 (m, 1F); IR (KBr) v: 3307, 3059, 2949, 1586, 1517, 1498, 1389, 1267, 1183, 1139, 1023, 821, 756 cm^{-1}; MS (70 eV) *m/z* (%): 343 ($[M]^+$, 46), 248 ($[M-C_6H_4F]^+$, 100). Anal. calcd for $C_{23}H_{18}FNO$: C 80.45, H 5.28, N 4.08; found C 80.18, H 5.41, N 4.07.

3,3-Dihydro-9-(3-fluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4ba) Yellow solid; m.p. 252—253 ℃; ^1H NMR (DMSO-d_6, 500 MHz) δ: 9.38 (s, 1H, NH), 8.49 (d, J=8.5 Hz, 1H, ArH), 7.83 (d, J=8.0 Hz, 1H, ArH), 7.60—7.47 (m, 3H, ArH), 7.34 (d, J=8 Hz, 1H, ArH), 7.23—7.19 (m, 1H, ArH), 7.05—6.86 (m, 3H, ArH), 5.29 (s, 1H, CH), 2.96—2.91 (m, 1H, CH), 2.74—2.68 (m, 1H, CH), 2.32—2.23 (m, 2H, CH_2), 2.02—1.88 (m, 2H, CH_2); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −113.75—−113.81 (m, 1F); IR (KBr) v: 3290, 3059, 2946, 1586, 1515, 1492, 1385, 1267, 1180, 1139, 1021, 795, 768 cm^{-1}; MS (70 eV) *m/z* (%): 343 ($[M]^+$, 31), 248 ($[M-C_6H_4F]^+$, 100). Anal. calcd for

Scheme 1 Tentative reaction pathways for the three-component coupling reaction



$C_{23}H_{18}FNO$: C 80.45, H 5.28, N 4.08; found C 80.41, H 5.27, N 3.98.

3,3-Dihydro-9-(4-fluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4ca) Yellow solid; m.p. 260—261 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.35 (s, 1H, NH), 8.48 (d, J=8.5 Hz, 1H, ArH), 7.82 (d, J=7.5 Hz, 1H, ArH), 7.59—7.46 (m, 3H, ArH), 7.29 (d, J=8.5 Hz, 1H, ArH), 7.25—7.21 (m, 2H, ArH), 7.01—6.97 (m, 2H, ArH), 5.27 (s, 1H, CH), 2.94—2.87 (m, 1H, CH), 2.74—2.67 (m, 1H, CH), 2.31—2.22 (m, 2H, CH_2), 2.01—1.86 (m, 2H, CH_2); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −117.45——117.81 (m, 1F); IR (KBr) v: 3283, 3058, 2940, 1584, 1516, 1491, 1386, 1268, 1181, 1139, 1021, 816, 756 cm^{-1}; MS (70 eV) *m/z* (%): 343 ($[M]^+$, 42), 248 ($[M-C_6H_4F]^+$, 100). Anal. calcd for $C_{23}H_{18}FNO$: C 80.45, H 5.28, N 4.08; found C 80.32, H 5.29, N 3.98.

3,3-Dihydro-9-(3,4-difluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4da) Yellow solid; m.p. 257—258 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.39 (s, 1H, NH), 8.49 (d, J=8.5 Hz, 1H, ArH), 7.83 (d, J=7.5 Hz, 1H, ArH), 7.60—7.48 (m, 3H, ArH), 7.34 (d, J=8.5 Hz, 1H, ArH), 7.26—7.19 (m, 2H, ArH), 7.02—6.99 (m, 1H, ArH), 5.29 (s, 1H, CH), 2.95—2.90 (m, 1H, CH), 2.74—2.68 (m, 1H, CH), 2.30—2.23 (m, 2H, CH_2), 2.02 — 1.89 (m, 2H, CH_2); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −139.16——139.25 (m, 1F), −142.65——142.74 (m, 1F); IR (KBr) v: 3285, 3056, 2956, 1589, 1517, 1498, 1388, 1265, 1184, 1139, 1025, 796, 759 cm^{-1}; MS (70 eV) *m/z* (%): 361 ($[M]^+$, 20), 248 ($[M-C_6H_3F_2]^+$, 100). Anal. calcd for $C_{23}H_{17}F_2NO$: C 76.44, H 4.74, N 3.88; found C 76.65, H 4.71, N 3.76.

3,3-Dihydro-9-(3,5-difluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4ea) Yellow solid; m.p. 257—258 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.41 (s, 1H, NH), 8.49 (d, J=8.5 Hz, 1H, ArH), 7.84 (d, J=8.0 Hz, 1H, ArH), 7.60—7.50 (m, 3H, ArH), 7.38 (d, J=8.5 Hz, 1H, ArH), 6.95—6.88 (m, 3H, ArH), 5.33 (s, 1H, CH), 2.97—2.92 (m, 1H, CH), 2.75—2.69 (m, 1H, CH), 2.33—2.25 (m, 2H, CH_2), 2.03—1.90 (m, 2H, CH_2); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −110.29——110.33 (m, 2F); IR (KBr) v: 3304, 3060, 2940, 1621, 1591, 1518, 1502, 1392, 1262, 1187, 1112, 826, 758 cm^{-1}; MS (70 eV) *m/z* (%): 361 ($[M]^+$, 27), 248 ($[M-C_6H_3F_2]^+$, 100). Anal. calcd for $C_{23}H_{17}F_2NO$: C 76.44, H 4.74, N 3.88; found C 76.26, H 4.75, N 3.91.

3,3-Dihydro-9-(pentafluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4fa) Yellow solid; m.p.＞300 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.51 (s, 1H, NH), 8.49 (d, J=8.5 Hz, 1H, ArH), 7.85 (d, J=8.0 Hz, 1H, ArH), 7.63—7.48 (m, 3H, ArH), 7.06 (d, J=8.5 Hz, 1H, ArH), 5.75 (s, 1H, CH), 2.87—2.81 (m, 1H, CH), 2.74—2.68 (m, 1H, CH), 2.32—2.18 (m, 2H, CH_2), 2.00—1.88 (m, 2H, CH_2); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −144.46——144.50 (m, 2F), −157.88——157.97 (m, 1F), −163.64——163.75 (m, 2F); IR (KBr) v: 3309, 3061, 2949, 1590, 1519, 1500, 1393, 1266, 1188, 1104, 1024, 801, 740 cm^{-1}; MS (70 eV) *m/z* (%): 415 ($[M]^+$, 11), 248 ($[M-C_6F_5]^+$, 24), 190 ($[M-C_9H_6F_5O]^+$, 100). Anal. calcd for $C_{23}H_{14}F_5NO$: C 66.51, H 3.40, N 3.37; found C 66.43, H 3.52, N 3.35.

3,3-Dimethyl-9-(2-fluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4ab) Yellow solid; m.p. 280—281 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.29 (s, 1H, NH), 8.46 (d, J=8.5 Hz, 1H, ArH), 7.80 (d, J=8.5 Hz, 1H, ArH), 7.59—7.44 (m, 3H, ArH), 7.26—7.23 (m, 1H, ArH), 7.19 (d, J=8.5 Hz, 1H, ArH), 7.12—7.00 (m, 3H, ArH), 5.51 (s, 1H, CH), 2.77 (d, J=17.5 Hz, 1H, CH), 2.68 (d, J=17 Hz, 1H, CH), 2.24 (d, J=16.5 Hz, 1H, CH), 2.03 (d, J=16 Hz, 1H, CH), 1.09 (s, 3H, CH_3), 1.04 (s, 3H, CH_3); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −119.01——119.06 (m, 1F); IR (KBr) v: 3271, 3053, 2959, 1583, 1517, 1491, 1386, 1257, 1152, 1057, 824, 756, 646 cm^{-1}; MS (70 eV) *m/z* (%): 371 ($[M]^+$, 47), 276 ($[M-C_6H_4F]^+$, 100). Anal. calcd for $C_{25}H_{22}FNO$: C 80.84, H 5.97, N 3.77; found C 80.64, H 6.01, N 3.69.

3,3-Dimethyl-9-(3-fluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4bb) Yellow solid; m.p. 233—234 ℃; ^{1}H NMR (500 MHz, DMSO-d_6) δ: 9.29 (s, 1H, NH), 8.46 (d, J=8.5 Hz, 1H, ArH), 7.80 (d, J=8.5 Hz, 1H, ArH), 7.59—7.44 (m, 3H, ArH), 7.26—7.23 (m, 1H, ArH), 7.19 (d, J=8.5 Hz, 1H, ArH), 7.12—7.00 (m, 3H, ArH), 5.51 (s, 1H, CH), 2.77 (d, J=17.5 Hz, 1H, CH), 2.68 (d, J=17 Hz, 1H, CH), 2.24 (d, J=16.5 Hz, 1H, CH), 2.03 (d, J=16 Hz, 1H, CH), 1.09 (s, 3H, CH_3), 1.04 (s, 3H, CH_3); ^{19}F NMR (470 MHz, DMSO-d_6) δ: −113.57——113.62 (m, 1F); IR (KBr) v: 3299, 3056, 2955, 1589, 1520, 1500, 1388, 1263, 1152, 1060, 874, 765, 614 cm^{-1}; MS (70 eV) *m/z* (%): 371 ($[M]^+$, 26), 276 ($[M-C_6H_4F]^+$, 100). Anal. calcd for $C_{25}H_{22}FNO$: C 80.84, H 5.97, N 3.77; found C 80.99, H 6.03, N 3.78.

3,3-Dimethyl-9-(4-fluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4cb)[10a] Yellow solid; m.p. 256—258 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.32 (s, 1H, NH), 8.48 (d, J=8.5 Hz, 1H, ArH), 7.83 (d, J=8 Hz, 1H, ArH), 7.60—7.47 (m, 3H, ArH), 7.31 (d, J=8.5 Hz, 1H, ArH), 7.24—7.19 (m, 1H, ArH), 7.05—6.87 (m, 3H, ArH), 5.26 (s, 1H, CH), 2.75 (d, J=17 Hz, 1H, CH), 2.66 (d, J=17 Hz, 1H, CH), 2.25 (d, J=16 Hz, 1H, CH), 2.07 (d, J=16 Hz, 1H, CH), 1.08 (s, 3H, CH_3), 0.99 (s, 3H, CH_3); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −117.41——117.47 (m, 1F); IR (KBr) v: 3289, 3044, 2959, 1579, 1517, 1493, 1388, 1265, 1222, 1154, 1057, 852, 813, 642 cm^{-1}; MS (70 eV) *m/z* (%): 371 ($[M]^+$, 41), 276 ($[M-C_6H_4F]^+$, 100). Anal. calcd for $C_{25}H_{22}FNO$: C 80.84, H 5.97, N 3.77; found C 80.50, H 6.17, N 3.54.

Crystal data for **4cb**, $C_{25}H_{22}FNO$: MW=371.14, orthorhombic, space group: *Pbca*, a=8.511(3) Å, α=90°; b=13.007(4) Å, β=90°; c=35.121(12) Å, γ=90°; V=3888(2) Å^3, Z=8, D_c=1.269 Mg/m^3, F(000)=1568, crystal size: 0.15 mm×0.12 mm×0.10 mm, theta range for data collection 2.32°—27.01°, limiting indices −10≤h≤9, −16≤k≤16, −34≤l≤44, reflections

collected/unique 17561/4198 [R(int) = 0.0610], completeness to theta = 27.01, 99.0%, max. and min. transmission 0.9917 and 0.9876, refinement method full-matrix least-squares on F^2, data/restraints/parameters = 4198/0/260, goodness-of-fit on F^2 = 0.937, final R indices [I>2sigma(I)] R_1 = 0.0468, wR_2 = 0.1124, R indices (all data) R_1 = 0.1002, wR_2 = 0.1306, extinction coefficient = 0.0012(4), largest diff. peak and hole = 0.143 and −0.120 e•Å^{-3}. CCDC number is 760560.

3,3-Dimethyl-9-(3,4-difluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4db) Yellow solid; m.p. 259—261 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.33 (s, 1H, NH), 8.48 (d, J=8.5 Hz, 1H, ArH), 7.83 (d, J=8 Hz, 1H, ArH), 7.60—7.48 (m, 3H, ArH), 7.31 (d, J=8.5 Hz, 1H, ArH), 7.26—7.20 (m, 2H, ArH), 7.00 (d, J=5 Hz, 1H, ArH), 5.26 (s, 1H, CH), 2.75 (d, J=16.5 Hz, 1H, CH), 2.66 (d, J=17 Hz, 1H, CH), 2.25 (d, J=16 Hz, 1H, CH), 2.07 (d, J=16 Hz, 1H, CH), 1.07 (s, 3H, CH_3), 0.99 (s, 3H, CH_3); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −139.27——139.36 (m, 1F), −142.63— −142.73 (m, 1F); IR (KBr) v: 3311, 3056, 2955, 1592, 1519, 1500, 1389, 1262, 1151, 1059, 874, 768, 608 cm^{-1}; MS (70 eV) m/z (%): 389 ([M]$^+$, 32), 276 ([M−$C_6H_3F_2$]$^+$, 100). Anal. calcd for $C_{25}H_{21}F_2NO$: C 77.10, H 5.44, N 3.60; found C 76.87, H 5.63, N 3.57.

3,3-Dimethyl-9-(3,5-difluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4eb) Yellow solid; m.p. 244—245 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.37 (s, 1H, NH), 8.48 (d, J=8.5 Hz, 1H, ArH), 7.84 (d, J=7.5 Hz, 1H, ArH), 7.61—7.49 (m, 3H, ArH), 7.35 (d, J=8.5 Hz, 1H, ArH), 6.95—6.88 (m, 3H, ArH), 5.23 (s, 1H, CH), 2.77 (d, J=17 Hz, 1H, CH), 2.67 (d, J=16.5 Hz, 1H, CH), 2.25 (d, J=16 Hz, 1H, CH), 2.09 (d, J=15.5 Hz, 1H, CH), 1.08 (s, 3H, CH_3), 1.00 (s, 3H, CH_3); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −110.33— −110.40 (m, 2F); IR (KBr) v: 3305, 3058, 2957, 1594, 1520, 1499, 1387, 1260, 1152, 1114, 1060, 988, 861, 759, 612 cm^{-1}; MS (70 eV) m/z (%): 389 ([M]$^+$, 30), 276 ([M−$C_6H_3F_2$]$^+$, 95), 80 ([M−$C_{20}H_{17}F_2N$]$^+$, 100). Anal. calcd for $C_{25}H_{21}F_2NO$: C 77.10, H 5.44, N 3.60; found C 76.90, H 5.45, N 3.50.

3,3-Dimethyl-9-(pentafluorophenyl)-1,2,3,4,9,10-hexahydrobenzo[*c*]acridine-1-one (4fb) Yellow solid; m.p. 214—215 ℃; ^{1}H NMR (DMSO-d_6, 500 MHz) δ: 9.46 (s, 1H, NH), 8.48 (d, J=8.5 Hz, 1H, ArH), 7.84 (d, J=8 Hz, 1H, ArH), 7.63—7.49 (m, 3H, ArH), 7.06 (d, J=8.5 Hz, 1H, ArH), 5.75 (s, 1H, CH), 2.68 (d, J=17 Hz, 1H, CH), 2.64 (d, J=16.5 Hz, 1H, CH), 2.24 (d, J=16 Hz, 1H, CH), 2.04 (d, J=16 Hz, 1H, CH), 1.08 (s, 3H, CH_3), 0.97 (s, 3H, CH_3); ^{19}F NMR (DMSO-d_6, 470 MHz) δ: −144.64——144.70 (m, 2F), −157.73——157.82 (m, 1F), −163.69——163.78 (m, 2F); IR (KBr) v: 3292, 3053, 2962, 1587, 1518, 1501, 1391, 1264, 1149, 1102, 991, 885, 793, 620 cm^{-1}; MS (70 eV) m/z (%): 443 ([M]$^+$, 44), 276 ([M−C_6F_5]$^+$, 64), 80 ([M − $C_{20}H_{14}F_5N$] $^+$, 100). Anal. calcd for $C_{25}H_{18}F_5NO$: C 67.72, H 4.09, N 3.16; found C 67.70, H 3.85, N 3.29.

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