

Received: December 21, 1977

SYNTHESIS AND NMR SPECTROSCOPY OF 2', 3', 4', 5', 6'-  
PENTAFLUOROFORMANILIDE

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SUMMARY

Pentafluoroformanilide was prepared by a new synthetical route. The  $^1\text{H}$ ,  $^{13}\text{C}$ , and  $^{19}\text{F}$  chemical shifts for the compound indicated the presence of cis and trans isomers in chloroform with a rotational energy barrier of  $13.4 \text{ Kcal mol}^{-1}$  for the N-C(O) bond.

N,N'-Bis(2,3,4,5,6-pentafluorophenyl)formamidine was obtained from pentafluoroformanilide.

INTRODUCTION

Some of the reactions in the program for forming poly-(iminoperfluorophenylene) derivatives have been performed in dimethylformamide [1,2]. Checking of possibilities for side-reactions with this solvent resulted in a new synthetical route to pentafluoroformanilide [3], and most probably to formanilides in general. A spectroscopic investigation was performed on pentafluoroformanilide, as published results found in acetone- $\text{d}_6$  and chloroform solutions were reported to show no evidence of coexistence of cis and trans isomers [3].

## RESULTS AND DISCUSSION

No reaction seemed to occur between N,N-dimethylformamide and lithium decafluorodiphenylamide or lithium 2,3,4,5,6-pentafluorodiphenylamide. But with N-lithium pentafluoroanilide in the presence of lithium amide (1:1), pentafluoroformanilide (1) was formed in good yield (62%) together with 2,3,5,6-tetrafluoro-4-(pentafluoroanilino)formanilide (4%). The reaction mechanism has not been examined, but may be a base catalyzed aminolysis [4,5]. Pentafluoroformanilide has previously been prepared from N-sodium pentafluoroanilide and ethyl formate in 55% yield [3].

The infrared spectrum of 1 in carbon tetrachloride showed two bands corresponding to free NH at 3405 and 3435  $\text{cm}^{-1}$  in the approximate ratio 2:3. These two bands concur with those for formanilide, viz. 3407 and 3437  $\text{cm}^{-1}$ , respectively, which are associated with the cis and trans configurations for formanilide arising from hindered rotation around the N-C(O) bond [6].

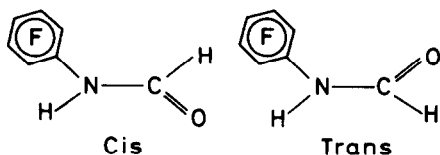


Fig. 1. Cis and trans isomers of 2', 3', 4', 5', 6'-pentafluoroformanilide.

The  $^1\text{H}$  spectra of pentafluoroformanilide have been observed earlier in an acetone- $\text{d}_6$  solution [3]. In the concentration range 6 to 30 w/v % no chemical shift variation was observed. The formyl proton was found at 8.52 ppm while the amido proton was found at 9.2 ppm. The formyl signal was found to be little influenced by change of solvent, whereas the amido proton was found to be shifted to high field, and showed a concentration dependence in chloroform- $\text{d}$ . The different behaviour in the two solvents has been interpreted as being due to an almost complete hydrogen bonded situation between the acetone- $\text{d}_6$  and the solute. In Table 1 the varia-

tion in chemical shift for the signals assigned to the two isomers is reported as function of concentration in chloroform-d.

Throughout the investigation (solutions 1-6, Table 1) the integral ratio between the two isomers was found to be constant. A reasonable estimate of the cis content is 43% over the whole range of concentrations in chloroform-d. It is known that solute-solute hydrogen bonding effects are reduced on dilution both for the cis and the trans forms of formanilide in chloroform [7]. The dimerization of formanilide in carbon tetrachloride has been studied by Belinskaya [8].

If we consider the amidoprotons in the cis compound and term the total mol concentration of this compound X, the conversion rate from cis to trans form can be neglected at 293 K (vide infra). The material balance reads

$$\alpha X + (1-\alpha)X = X \quad (1)$$

where  $\alpha X$  is the concentration of the monomeric cis molecules and  $(1-\alpha)X$  the concentration of hydrogen bonded cis molecules. The hydrogen bonding may take place to a cis or a trans form of the same compound in solution.

The observed chemical shift  $\delta$  is the weighted average of the free and hydrogen bonded species

$$\delta = \alpha \delta_{\text{free}} + (1-\alpha) \delta_{\text{bound}} \quad (2)$$

If the  $\delta$  value observed in acetone is inserted as  $\delta_{\text{bound}}$  and the extrapolated values for infinite dilutions are used for  $\delta_{\text{free}}$ , we obtain the expression

$$\frac{\delta_{\text{bound}} - \delta}{\delta_{\text{bound}} - \delta_{\text{free}}} = \alpha \quad (3)$$

This expression is used to estimate the proportion of monomeric molecules in chloroform-d as indicated in Table 1.

The assumptions involved in the determination of  $\alpha$  make the present values only indicative, but they do reflect the

TABLE 1

$\delta^1\text{H}$  for 2', 3', 4', 5', 6'-pentafluoromannilide in  $\text{CDCl}_3$  at different concentrations downfield to  $\text{CHCl}_3$  as internal standard at 270 MHz and 293 K

Solut- ion	Total concen- tration mol/l	obs. $\delta_{\text{CH}}$ in Hz (ppm)		obs. $\delta_{\text{NH}}$ in Hz (ppm)		$\alpha_{\text{transa}}$	$\alpha_{\text{cisa}}$
		trans	cis	trans	cis		
1	0.00173	358.5(1.33)	327.0(1.21)	$\sim 0(\sim 0)$	-120.0(-0.44)	1.00	1.00
2	0.0305	354.0(1.31)	324.0(1.20)	$\sim 40(\sim 0.15)$	-88.5(-0.33)	0.92	0.95
3	0.0967	351.8(1.30)	321.8(1.19)	106.5(0.39)	-21.0(-0.08)	0.80	0.84
4	0.1450	351.0(1.30)	321.0(1.19)	153.0(0.57)	+18.0(+0.07)	0.71	0.78
5	0.1933	349.5(1.29)	319.5(1.18)	181.5(0.67)	+48.0(+0.18)	0.65	0.74
6	0.3578	346.4(1.28)	316.0(1.17)	223.9(0.83)	+102.4(+0.38)	0.57	0.65
Lim C $\rightarrow$ O		358.8(1.33)	327.2(1.21)	0 (0)	-121.2(-0.45)		

a) assuming complet hydrogen bonding for NH in acetone- $d_6$  corresponding to 9.2 ppm = 521 Hz from  $\text{CHCl}_3$ .

extent to which the monomer (or non hydrogen bonded species) are present in chloroform-d.

In Table 2  $^{13}\text{C}$  data for formanilide, acetanilide and pentafluoroformanilide have been collected. Formanilide data have been obtained by Nakanishi and Yamamoto [9], but no chemical shift data were reported. Using the intensity ratios found in the carbon spectra of the same compound we found the cis isomer to be present in 33%; this agrees well with published results [9]. The shifts in the fluorine decoupled carbon spectrum have been assigned using the intensity ratio found in the proton spectra, the shift differences found between cis and trans isomers in formanilide, and data published previously [10].

In the proton decoupled carbon spectrum the carbon resonances due to the pentafluorophenyl group constitute a broad unresolved band. The formyl carbon, on the contrary, at low temperatures, i.e. 273 K to 303 K, exhibits two sharp signals due to the cis and trans isomers. In order to study the hindered rotation over a wide range of temperatures a saturated solution of 1 in  $\text{CHCl}_2 \cdot \text{CHCl}_2$  was studied. Here the chemical shift difference for the formyl carbon was observed to be 270 Hz (3.98 ppm) allowing the observation of the broadening and coalescence of the two signals over a temperature range of 80 degrees. The spectrum was observed at 11 temperatures from 303 K to 373 K, and the interpretation is based on the following assumptions. Firstly, the relative populations of the two isomers were taken as 43% and 57% over the whole range based on intensity measurements for the formyl proton over the temperature range 293 K to 335 K where no significant changes were observed. (The intensities observed in the carbon spectra with sharp signals agree with the finding in the proton spectra.) Secondly, that the relaxation times  $T_2$  in the two isomers are equal and do not change over the range of temperatures studied. In the low temperature range where two signals are still resolved the separation between the two maxima was measured and compared to the calculations. In the range of coalescence (338 K) the full line shape was



plotted and matched to the observed spectra. At high temperatures the half line width was measured and compared to the calculated spectra. The obtained data were subsequently interpreted using the semilogarithmic Eyring and Arrhenius plots to obtain  $\Delta H^\ddagger$ ,  $\Delta S^\ddagger$ ,  $E_a$  and  $\log A$ . The values obtained are  $\Delta H^\ddagger = 12.7 \text{ Kcal mol}^{-1}$ ,  $\Delta S^\ddagger = 8.2 \text{ e.u.}$ ,  $E_a = 13.4 \text{ Kcal mol}^{-1}$  and  $\log A = 11.51$ .

As discussed by Dahlquist [11] the systematic errors in the treatment introduce an uncertainty of 1 to 2  $\text{Kcal mol}^{-1}$  in the obtained values. Taking this into consideration it is still obvious that the values found are significantly lower than the 20  $\text{Kcal mol}^{-1}$  reported in formanilide [9]. This could be interpreted as a reduced double bond character in the C-N amide bond due to the increased electron withdrawing ability of the pentafluorophenyl group over that of  $\text{C}_6\text{H}_5$ .

The fluorine chemical shifts in acetone concur with previously published results [3]. The spectrum in chloroform-d has been shown in Fig. 2. The chemical shifts have been assigned using the intensity ratios determined above.

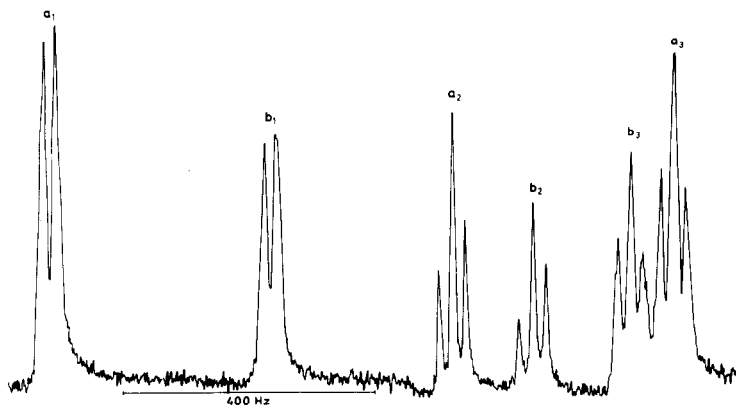


Fig. 2.  $^{19}\text{F}$  NMR spectrum of 2', 3', 4', 5', 6'-pentafluoroformanilide in  $\text{CDCl}_3$ . The chemical shifts are given in ppm downfield to  $\text{C}_6\text{F}_6$  (with  $\text{CF}_3\text{CCl}_3$  as internal standard) for the trans (a) and cis (b) isomers:  $a_1$  (17.9, o),  $a_2$  (6.5, p),  $a_3$  (0.2, m),  $b_1$  (11.7, o),  $b_2$  (4.2, p),  $b_3$  (1.4, m).

1 was hydrolyzed to pentafluoroaniline when treated with diluted sodium hydroxide for 2 hours at 70  $^\circ\text{C}$ . N,N'-Bis-

(pentafluorophenyl)formamidine, not the expected N-difluoromethylpentafluoroformanilide, was sublimed from the reaction mixture between 1 and difluorocarbene in diluted sodium hydroxide [12]. Formamidines result also from reactions between anilines and chloroform in the presence of potassium hydroxide [13].

## EXPERIMENTAL

### Spectroscopic data

Infrared spectra were obtained with a Perkin-Elmer 457-IR instrument. Mass spectra were recorded on an AEI MS 902 instrument attached to an AEI DS30 system.

<sup>1</sup>H spectra have been recorded on a Bruker HX 270S spectrometer operating at a frequency of 270 MHz. Ambient temperature was 293 K. Fourier transform mode was used with 16 K data points and a spectral width of 3000 Hz. The sample concentrations varied and are given in Table 1. The number of scans ranged from 400 for the strongest solutions to 10 000 for the weakest. A pulse angle of 40° was used with no delay between scans. All samples were prepared in 5 mm tubes from CDCl<sub>3</sub> and pentafluoroformanilide without degassing. In the integration of the spectra, digital integration using Romberg integration [14] was used.

<sup>13</sup>C spectra were recorded on the Bruker HX 270S at 67.889 MHz. 32 K data points were used for a spectral width of 17 000 Hz. A pulse width of 8 μsec corresponding to 50° was used. No delay was introduced between scans. Broad band decoupling was applied. Chemical shifts were referenced to CDCl<sub>3</sub> as a secondary standard [15]. The rotational barrier in 1 was determined using a solution of 0.379 gram 1 in 1.5 ml CHCl<sub>2</sub>CHCl<sub>2</sub> and 0.4 ml C<sub>6</sub>D<sub>6</sub>.

<sup>19</sup>F spectra were recorded on a Bruker HFX at 56.4 MHz. To obtain good S/N ratios a Varian C1024 CAT was used to accumulate 200 scans. Spectral width was 60 Hz sweep rate 0.6 Hz/sec. Samples were contained in 5 mm tubes where approx. 50 mg of the compounds were dissolved in 500 μl CDCl<sub>3</sub>. CCl<sub>3</sub>CF<sub>3</sub> or C<sub>6</sub>F<sub>6</sub> were added as reference compounds [16].



Synthesis2', 3', 4', 5', 6'-Pentafluoroformanilide

Pentafluoroaniline (11.0 g, 0.06 mol) was added slowly to lithium amide (3.2 g) in dried [1,2] THF (20 ml) at 0 °C under oxygen-free nitrogen, whereupon DMF (15 ml) was added. The mixture was warmed to reflux and gave a black mixture with a white precipitate. A gas was slowly formed, and the colour gradually changed, becoming bluish and then reddish-violet. After 4 hours at reflux, the mixture was cooled, hydrolyzed and worked up. This gave by sublimation (60 °C, 0.01 mmHg) 7.80 g (61.6%) pentafluoroformanilide, m.p. 99-101 °C (in a closed vial). The formanilide dissolves in warm water. Found: C, 40.23; H, 1.23; m/e as in [3]. Calc. for  $C_7H_2F_5NO$ : C, 39.93; H, 0.96. Further sublimation (150 °C, 0.01 mmHg) gave 0.46 g (4.1%) 2,3,5,6-tetrafluoro-4-(pentafluoroanilino)formanilide (n.c.), m.p. 185-187.5 °C. Found: C, 42.02; H, 1.04. Calc. for  $C_{13}H_3F_9N_2O$ : C, 41.73; H, 0.81. MS [IP 70 eV; m/e (% rel.int.)] 375 (12), 374 (83,M), 347 (10), 346 (77), 345 (18), 307 (14), 179 (100), 152 (13). Mol.wt. calc. 374.2.  $^{19}F$  NMR [56.4 MHz,  $(CD_3)_2CO$ , downfield to  $C_6F_6$ ]:  $\delta$  16.4, 10.3, 7.5, -1.5; rel.int. 2:2:2:3.

N,N'-Bis(2,3,4,5,6-pentafluorophenyl)formamidine

Pentafluoroformanilide (2.11 g, 0.01 mol) was dissolved in dioxane (8 ml) to which water (8 ml) and sodium hydroxide (2.00 g, 0.05 mol) were added. Chlorodifluoromethane (5.0 g) was bubbled slowly into the warm mixture over 25 min. A -70 °C reflux cooler was employed. The mixture was stirred for 1 hour at ambient temperature, and more water (100 ml) was added. The precipitate formed was filtered off, washed with water, dissolved in ether, dried and worked up by sublimation (120 °C, 0.05 mmHg) to give 0.65 g (34.6%) N,N'-bis(2,3,4,5,6-pentafluorophenyl)formamidine (n.c.), m.p. 162-163 °C. Found: C, 41.39; H, 0.66. Calc. for  $C_{13}H_2F_{10}N_2$ : C, 41.51; H, 0.54. MS [IP 70 eV; m/e (% rel.int.)] 376 (34,M), 357 (7), 356 (16),

194 (35), 184 (7), 183 (100), 167 (14). Mol.wt. calc. 376.2.

$^1\text{H}$  NMR (60 MHz,  $\text{CDCl}_3$  saturated):  $\delta$  8.26 (CH), 7.57 (NH).

The filtrate was extracted with ether and worked up to give 0.27 g recovered pentafluoroformanilide and an oil (1.0 g), which contained three compounds in approximately equal amounts.

#### REFERENCES

- 1 R. Koppang, *J. Organomet. Chem.*, 46 (1972) 193.
- 2 R. Koppang, *J. Fluorine Chem.*, 8 (1976) 389.
- 3 R.E. Banks, R.N. Haszeldine and B.G. Willoughby, *J. Chem. Soc. Perkin Trans.*, 1 (1975) 2451.
- 4 M.E. Smith and H.J. Adkins, *J. Am. Chem. Soc.*, 60 (1938) 657.
- 5 K.G. Wyness, *Macromol. Chem.*, 38 (1960) 189.
- 6 I. Suzuki, M. Tsuboi, T. Shimanouchi and S. Mizushima, *Spectrochim. Acta*, 16 (1960) 471.
- 7 H.J.R. Bourn, D.G. Gillies and E.W. Randall, *Tetrahedron*, 20 (1964) 1811.
- 8 L.G. Belinskaya, *Chem. Abstr.*, 81 (1974) 119752j and 84 (1976) 58418t.
- 9 H. Nakanishi and O. Yamamoto, *Chem. Letters (Japan)*, (1974) 521.
- 10 J.M. Briggs and E.W. Randall, *J. Chem. Soc. Perkin II*, (1973) 1789.
- 11 K.I. Dahlquist, *Acta Chem. Scand.*, 24 (1970) 683.
- 12 R. Koppang, *J. Fluorine Chem.*, 11 (1978) 19.
- 13 M. Ridi, *Gazz. Chim. Ital.*, 77 (1947) 3,10.
- 14 Bruker FT Program for Nicolet 1180.
- 15 The chemical shift of  $\text{CDCl}_3$  was assumed to be 76.90 ppm. G.C. Levy and J.D. Cargioli, *J. Magn. Reson.*, 6 (1972) 143.
- 16 The chemical shift for  $\text{C}_6\text{F}_6$  was 80.74 ppm highfield to  $\text{CCl}_3\text{CF}_3$  in  $\text{CDCl}_3$ .