REACTION OF para-SUBSTITUTED AROMATIC ACIDS WITH METHYL THIOCYANATE IN TRIFLUOROACETIC ACID

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We have investigated the reactions of aromatic carboxylic acids (p-XC_6H_4COOH, in which X = F, Cl, Br, I, NO_2, CH_3, H, OCH_3) with methyl thiocyanate in trifluoroacetic acid. It was shown that the starting acids are converted to S-methyl benzothioates [p-$XC_6H_4COSCH_3$ (40-70%)] and the nitrile of the acid [p-XC_6H_4CN (20-50%)]. In addition to starting acid, in the reaction mixtures products of the reaction of CF_3COOH with methyl thiocyanate were identified.

Keywords: methyl thiocyanate, trifluoroacetic acid, S-methyl benzothioates, methyl mercaptan.

Earlier it was found that the main products of the reaction of the strong mineral acid orthophosphoric acid with methyl thiocyanate (MTC) are esters of isothiocyanatothiophosphoric acid [1]. The less strong trifluoroacetic acid (TFA) on reaction with MTC gives two main products: S-methyl trifluoroacetylthioate and S-methyl trifluoroacetylthiocarbamate [2]. Aliphatic acids that are weaker than TFA give by refluxing with MTC in TFA S-methyl alkanethioates and S-methyl alkanethiocarbamates [3]. Reactions of stronger aromatic acids with MTC had not been investigated.

This is the reason we have investigated the behavior of a series of para-substituted aromatic acids with MTC in TFA by the method of chromato-mass spectroscopy. We have found that S-methyl esters are formed in rather high yields:

$$p\text{-X}{-}C_6H_4COOH + CH_3SCN \rightarrow \underset{(1-8)}{p\text{-}C_6H_4COSCH_3}$$

$$\text{X}=\text{H}\ (1);\quad OCH_3\ (2);\quad CH_3\ (3);\quad NO_2\ (4);\quad \text{F}\ (5);\quad \text{Cl}\ (6);\quad \text{Br}\ (7);\quad \text{I}\ (8).$$

S-Methyl arylthiocarbamates have not been described before. Probably they are more reactive and decompose at higher rates than S-methyl alkylthiocarbamates.

Just as in the case of aliphatic acids, in the aromatic series, in addition to S-methyl benzothioates, derivatives of trifluoroacetic acid are formed: S-methyl trifluoroacetylthioate (9) (21%), S-methyl trifluoroacetylthiocarbamate (10) (15%), and N-(trifluoroacetyl)-trifluoroacetamide (11) (13%) [2].

Compound 11 may be formed as a result of TFA-catalyzed thermolysis of 10 [2]. The formation of S-methyl trifluoroacetylthioate, by the way just as thioates 1-8, may proceed also by an alternative mechanism which includes reaction with CH_3SH. Methyl mercaptan itself may be formed by at least two routes.

The first includes the stage of transamidation of thiocarbamate 10 under influence of TFA. Thereby are formed compound 11 and S-methyl thiocarbonate (12), which decomposes to CO_2 and methyl mercaptan (13).

$$CF_3COOH + (10) \rightarrow (11) + \underset{(12)}{[CH_3S{-}C({=}O)OH]} \rightarrow \underset{(13)}{CH_3SH} + CO_2$$

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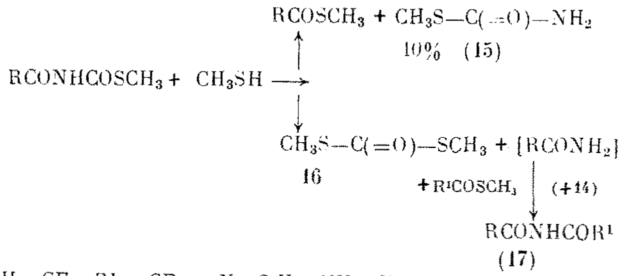
On the other hand, probably TFA and thioate (11) are in equilibrium with trifluoroacetic anhydride (14) and methyl mercaptan. As follows from data of chromato-mass spectroscopy, the latter two compounds are present in all the reaction mixtures studied:

$$CF_3COOH+CF_3COSCH_3 \rightleftharpoons \underset{(14)}{CF_3CO{-}O{-}COCF_3}+CH_3SH$$

Compound 13, which accumulates in the reaction mixture, may decompose thiocarbamates at two carbonyl carbon atoms: to thioates and 2-thiapropionamide (15) by one route, and to di-(S-methyl) dithiocarbonate (16) and the amide of the carboxylic acid, which is further acylated by compound 16 and thioates 1-8, which are present in the reaction mixture, with formation of 17:



$R = p\text{-}X{-}C_6H_4$, CF_3; $R^1 = CF_3$, $p\text{-}X{-}C_6H_4$, NH_2; $X = H$, OCH_3, CH_3, NO_2, F, Cl, Br, I.

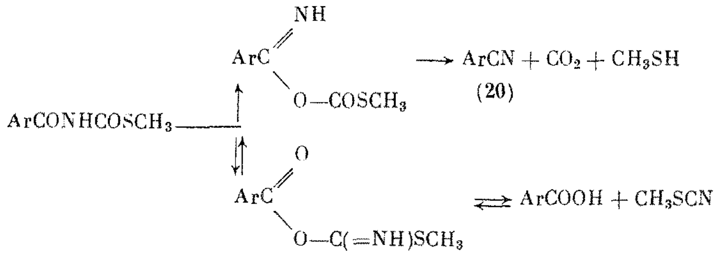
Amides of aromatic acids were not detected in the reaction mixture; however, caproamide (18) was isolated from the reaction of caproic acid with methyl thiocyanate under similar conditions, which serves as a confirmation of the theoretical possibility of their formation:

$$n\text{-}C_5H_{11}COOH+CH_3SCN+CF_3COOH \rightarrow \underset{17\%\quad(18)}{n\text{-}C_5H_{11}CONH_2}$$

Compound 15 partially dimerizes according to the scheme given above, yielding N-(2-thiapropionyl)urea (19):

$$\underset{(15)}{2CH_3SCONH_2} \rightarrow \underset{(19)}{CH_3SCONHCONH_2}+CH_3SH$$

The relatively low yield of thiol esters of aromatic acids induced us to carry out a series of similar reactions. In spite of a three- to fivefold excess of MTC relative to the starting acid, unchanged starting acid remained in the reaction mixtures and its nitrile was formed in yields of up to 50%. Probably, also in the case of transnitrilation reactions the methyl thioacarbamate formed after the first reaction isomerizes by two routes:



$Ar = p\text{-}X{-}C_6H_4$; $X = H$, OCH_3, CH_3, NO_2, F, Cl, Br, I.

Yields of Aromatic Nitriles $p\text{-}XC_6H_4CN$ (wt. %)

X	H	OCH_3	CH_3	NO_2	F	Cl	Br	I
%	31	29	42	21	21	37	19	47

Nitriles and acids may also be formed by an alternative route in the case of catalyzed thermolysis of symmetrical benzamides 17 [4].

Methyl mercaptan takes part in at least three other reactions. It couples with starting MTC and 2,4-dithiapentanimine-3 (21) is identified mass spectroscopically:

$$CH_3SCN+CH_3SH \rightarrow CH_3S{-}C({=}NH){-}SCH_3 \quad (21)$$

When air is bubbled through the reaction mixture, dimethyl disulfide (22) is formed:

$$13+O_2 \rightarrow CH_3{-}S{-}S{-}CH_3 \quad (22)$$

Thiolysis of compound 19 leads to isolation of N-(2-thiapropionyl)-2-thiapropionamide (23) from the reaction mixture:

$$CH_3SCONHCONH_2+CH_3SH \rightarrow CH_3SCONHCOSCH_3 \quad (23)$$

Thus, with weakening of the acid properties of the substrate, the reactivity of the acid with regard to MTC drops sharply. MTC reacts with boiling TFA with formation of trifluoroacetylthioate and other products.

Aliphatic (aromatic) acids do not react with MTC under mild conditions without catalyst. Formation of thiol esters of carboxylic acids is found only in refluxing TFA or at high temperatures: exposing a mixture of MTC and carboxylic acid to 200°C leads to formation of traces of thiol ester.

An insignificant difference in pK_a of aliphatic and aromatic acids causes that in the second case we failed to isolate thiocarbamates.

EXPERIMENTAL

Mass spectra were obtained on a KRATOS 25 RF mass spectrometer with treating of the data with DS-90 (ionization energy of the electrons 70 eV, temperature of the ionization chamber 260°C) and using a capillary column (25 m) with SE-30 as immobile liquid phase and temperature programmation: 5 deg/min in the interval 30-150°C and 10 deg/min in the interval 150-300°C.

IR spectra were taken on a Bruker IF-48 spectrometer from films and CCl_4 solutions.

Reaction of Aromatic Acids (1-8) with MTC. a. To a solution of 0.1 mole of acid in 0.5 mole of TFA is added 0.3 mole of MTC. The reaction mixture is refluxed for 2 h, the crystalline precipitate is filtered off, the liquid fraction containing thiol esters of 1-8 and aromatic nitriles 20 is fractionated under vacuum. The crystalline precipitate is dissolved in benzene and separated by chromatography over SiO_2, eluent benzene–alcohol, 5:1. Yields of products were determined by GLC by using authentic samples. Benzonitriles 17, methyl mercaptan, and trifluoroacetic anhydride were identified by means of authentic samples and by data of chromato-mass spectra by using reference spectra [5].

b. A mixture of 0.01 mole of acid is mixed with 0.03 mole of MTC and exposed in a miniature autoclave for 2 h. Analysis of products was carried out by means of chromato-mass spectroscopy.

S-Methyl benzothioate (1), yield 55%, bp 92°C (4 mm). Mass spectrum. m/z (I_{rel}, %): 152 $[M]^+$ (10), 105 $[M{-}SCH_3]^+$ (100), 77 $[Ph]^+$ (84), 75 $[COSCH_3]^+$ (3), 51 (72), 50 (30), 47 (5), 45 (20), 39 (12). IR spectrum (ν, cm^{-1}): 1662 $[C{=}O(SCH_3)]$. Found %: C 63.41, H 5.21. C_8H_8OS. Calculated, %: C 63.13, H 5.30.

S-Methyl p-methoxybenzothioate (2), yield 59%, bp 138-140°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 182 $[M]^+$ (5), 135 $[M{-}SCH_3]^+$ (100), 107 $[C_6H_4OCH_3]^+$ (24), 92 $[C_6H_4O]^+$ (35), 77 (43), 64 (20), 51 (2), 50 (3), 47 $[C{=}O(SCH_3)]^+$ (2), 45 (5), 39 (1). IR spectrum (ν, cm^{-1}): 1662 $[C{=}O(SCH_3)]$. Found, %: C 59.46, H 5.43. $C_9H_{10}O_2S$. Calculated, %: C 59.32, H 5.53.

S-Methyl p-methylbenzothioate (3), yield 45%, bp 91-93°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 166 $[M]^+$ (5), 151 $[M{-}CH_3]^+$ (2), 119 $[M{-}SCH_3]^+$ (100), 91 $[C_6H_4CH_3]^+$ (54), 65 (20), 51 (2), 39 (10). IR spectrum (ν, cm^{-1}): 1663 $[C{=}O(SCH_3)]$. Found, %: C 65.37, H 5.89. $C_9H_{10}OS$. Calculated, %: C 65.02, H 6.06.

S-Methyl p-nitrobenzothioate (4), yield 70%, bp 149-150°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 197 $[M]^+$ (4), 150 $[M{-}SCH_3]^+$ (100), 120 (20), 104 $[M{-}SCH_3{-}NO_2]^+$ (63), 92 (48), 76 $[M{-}NO_2{-}SCH_3]^+$ (81), 75 $[COSCH_3]^+$ (35), 64 (15), 50 (10), 43 (80), 39 (22). IR spectrum (ν,

cm^{-1}): 1663 [C=O(SCH_3)]. Found, %: C 48.83, H 3.64. $C_8H_7O_3NS$. Calculated, %: C 48.72, H 3.59.

S-Methyl p-fluorobenzothioate (5), yield 63%, bp 94-96°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 170 $[M]^+$ (20), 123 $[M-SCH_3]^+$ (100), 95 $[C_6H_4F]^+$ (70), 75 $[COSCH_3]^+$ (30), 69 (10), 51 (5), 50 (10). IR spectrum (ν, cm^{-1}): 1663 [C=O(SCH_3)]. Found, %: C 56.16, H 37.98. C_8H_7FOS. Calculated, %: C 56.46, H 4.15.

S-Methyl p-chlorobenzothioate (6), yield 52%, bp 100-102°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 186 $[M]^+$ (10), 139 $[M-SCH_3]^+$ (100), 111 $[C_6H_4Cl]^+$ (60), 75 $[COSCH_3]^+$ (60), 69 (45), 51 (40), 50 (65), 47 $[SCH_3]^+$ (50). IR spectrum (ν, cm^{-1}): 1663 [C=O(SCH_3)]. Found, %: C 51.54, H 3.65. C_8H_7ClOS. Calculated, %: C 51.48, H 3.78.

S-Methyl p-bromobenzothioate (7), yield 67%, bp 103-105°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 230 $[M]^+$ (4), 150 $[M-SCH_3]^+$ (100), 156 $[C_6H_4Br]^+$ (42), 75 $[COSCH_3]^+$ (40), 64 (15), 50 (43). IR spectrum (ν, cm^{-1}): 1663 [C=O(SCH_3)]. Found, %: C 41.53, H 3.10. C_8H_7BrOS. Calculated, %: C 41.58, H 3.05.

S-Methyl p-iodobenzothioate (8), yield 45%, bp 109-112°C (1 mm). Mass spectrum, m/z (I_{rel}, %): 278 $[M]^+$ (5), 231 $[M-SCH_3]^+$ (48), 230 $[M-SCH_3]^+$ (30), 203 $[C_6H_4I]^+$ (20), 127 $[I]^{+\cdot}$ (20), 102 (72), 76 (91), 75 $[COSCH_3]^+$ (40), 69 (65), 51 (50), 50 (100). IR spectrum (ν, cm^{-1}): 1658 [C=O(SCH_3)]. Found, %: C 34.35, H 2.67. C_8H_7IOS. Calculated, %: C 34.55, H 2.54.

S-Methyl 2,2,2-trifluoroethanethioate (9), yield 21% calculated on MTC, bp 67°C. Mass spectrum, m/z (I_{rel}, %): 144 $[M]^{+\cdot}$ (15), 97 $[CF_3CO]^+$ (3), 75 $[COSCH_3]^+$ (100), 69 $[CF_3]^+$ (60), 47 $[SCH_3]^+$ (33), 45 (25). The PMR spectrum was similar to that mentioned in [2]. IR spectrum (ν, cm^{-1}): 1706 (C=O).

S-Methyl N-trifluoroacetylthiocarbamate (10), yield 15% calculated on MTC used in the reaction, mp 56°C. Mass spectrum m/z (I_{rel}, %): 187 $[M]^{+\cdot}$ (13), 112 $[M-CF_3CONH]^+$ (5), 97 $[CF_3CO]^+$ (4), 75 $[COSCH_3]^+$ (8), 70 $[CF_3H]^+$ (100), 69 $[CF_3]^+$ (70), 47 $[SCH_3]^+$ (60). IR spectrum (ν, cm^{-1}): 1747 [C=O(CF_3)], 1665 [$COSCH_3$], 3300-3500 (NH). Found, %: C 26.01, H 7.35. $C_4H_4F_3NO_2S$. Calculated, %: C 25.57, H 7.49.

N-(trifluoroacetyl)trifluoroacetamide (11), yield 13% calculated on MTC, mp 86°C. Mass spectrum m/z (I_{rel}, %): 209 $[M]^+$ (8), 140 $[M-CF_3]^+$ (10), 112 $[M-CF_3CO]^+$ (28), 97 $[CF_3CO]^+$ (12), 69 $[CF_3]^+$ (95), 51 (13), 45 (100). IR spectrum (ν, cm^{-1}): 1747 [C=O(CF_3)], 3300-3500 (NH). Found, %: C 22.98, H 6.70. $C_4HF_6NO_2$. Calculated, %: C 22.68, H 6.91.

2-Thiapropionamide (15), yield 5% calculated on MTC, mp 103-105°C. Mass spectrum , m/z (I_{rel}, %): 91 $[M]^+$ (30), 75 $[M-NH_2]^+$ (3), 48 $[CH_3SH]^+$ (100), 47 $[SCH_3]^+$ (70). IR spectrum (ν, cm^{-1}): 1659, 1635 (C=O), 3368, 3249 (NH_2).

Di-S-methyl dithiocarbonate (16). Mass spectrum, m/z (I_{rel}, %): 122 $[M]^{+\cdot}$ (40), 94 $[M-CO]^+$ (45), 75 $[COSCH_3]^+$ (100), 47 $[SCH_3]^+$ (72), 45 (70).

Caproamide (18). Preparation and isolation were carried out similar to the crystalline derivative of trifluoroacetic acid. mp 101°C. Mass spectrum, m/z (I_{rel}, %): 115 $[M]^+$ (5), 99 $[M-NH_2]^+$ (10), 100 $[M-CH_3]^+$ (5), 86 (21), 72 (36), 59 (100), 44 (70), 43 (47).

N-(Thia-2-propionyl)urea (19), yield 6%, mp 319°C (dec.). Mass spectrum, m/z (I_{rel}, %): 134 $[M]^{+\cdot}$ (5), 91 $[M-CONH]^+$ (4), 87 $[M-SCH_3]^+$ (35), 86 (12), 75 $[COSCH_3]^+$ (5), 70 $[NH_2CONH_2]^{+\cdot}$ (15), 48 $[CH_3SH]^{+\cdot}$ (60), 47 $[SCH_3]^+$ (43), 44 $[CONH_2]^+$ (100), 43 (22). IR spectrum (ν, cm^{-1}): 1690, 1662 (C=O), 3390, 3308, 3223 (NH).

2,4-Dithiapentanimine-3 (21). Mass spectrum, m/z (I_{rel}, %): 121 $[M]^{+\cdot}$ (8), 74 $[M-SCH_3]^+$ (73), 47 $[SCH_3]^+$ (82), 73 (70), 72 (50), 48 (42), 45 (100).

Dimethyl disulfide (22). Mass spectrum, m/z (I_{rel}, %): 94 $[M]^{+\cdot}$ (100), 79 $[M-CH_3]^+$ (63), 47 $[SCH_3]^+$ (32).

N-(2-Thiapropionyl)-2-thiapropionamide (23), yield 7%, mp 113°C. Mass spectrum, m/z (I_{rel}, %): 165 $[M]^{+\cdot}$ (3), 118 $[M-SCH_3]^+$ (30), 75 $[COSCH_3]^+$ (100), 70 (20), 47 (50). IR spectrum (ν, cm^{-1}): 1701, 1637 (CO), 3164, 3076 (NH). Found, %: C 29.45, H 4.30. $C_4H_7NO_2S_2$. Calculated, %: C 29.08, H 4.27.

LITERATURE CITED

1. M. G. Zinin, R. M. Kamalov, R. A. Cherkasov, and A. N. Pudovik, Zh. Obshch. Khim., 52, No. 3, 482 (1982).
2. Yu. N. Polivin and E. A. Ageev, Izv. Akad. Nauk, Ser. Khim., No. 1, 195 (1991).
3. Yu. N. Polivin, V. A. Vinokurov, M. A. Silin, and R. A. Karakhanov, Izv. Vyssh. Uchebn. Zaved., Khim. Khim. Tekhnol., 33, No. 8, 109 (1990).
4. E. N. Zil'berman, Usp. Khim., 29, No. 6, 709 (1960).
5. E. Stenhagen, A. Abrahamson, and F. McLaferty (eds.), Atlas of Mass Spectral Data, Interscience, New York (1969).