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STUDIES ON ORGANOPHOSPHORUS COMPOUNDS XX.[a]
SYNTHESES OF THIOKETONES

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ABSTRACT - Substituted benzophenones, 2-benzoylthiophene, 3-benzoylpyridine, dicyclopropyl ketone, and camphor are converted into the corresponding thioketones after reaction with the dimer of *p*-methoxyphenylthionophosphine sulfide, **1**. Except for the pyridine derivatives (2- and 4-benzoylpyridines, respectively, gave no thioketones) very high yields are found. Under the same conditions dibenzylketone gave 1,3-diphenylpropene-2-thiol and 1,9-benzanthr-10-one yielded the dimer of 1,9-benzanthr-10-thione. Aromatic thioketones are also obtained by reacting gem-dichlorides with 2-methyl-2-propanethiol in the presence of catalytic amounts of CF_3COOH (or $AlCl_3$). A mechanism is suggested based on kinetic measurements. ^{13}C NMR data of the thiocarbonyls of all thioketones are recorded and a function describing the relation between the chemical shifts of C=S and C=O is found:

$$\delta_{C=S} = 1.57\,\delta_{C=O} - 71.45$$

INTRODUCTION

The most common procedures for the preparation of thioketones are the reactions of ketones with H_2S + HCl[1] or with P_4S_{10} + $NaHCO_3$.[2] Other thiation agents like organic P,S-compounds are known and in a few cases they have been employed for conversion of ketones into thioketones.[3-5] Lately, a series of P,S-containing thiation agents have been used for the synthesis of different types of thiocarbonyl derivatives.[6-8] A classical procedure for the preparation of aromatic thioketones is thiation of gem-dichlorides with reagents like sodium hydrogensulfide,[9] potassium xanthate,[10] or thioacetic acid.[11] This paper will report on syntheses of thioketones from the reactions of ketones with the dimer of *p*-methoxyphenylthionophosphine sulfide and briefly, on reactions of gem-dichlorides with 2-methyl-2-propanethiol.

RESULTS AND DISCUSSIONS

A. Thioketones from ketones. Ketones react smoothly with the dimer of *p*-methoxyphenylthionophosphine sulfide, **1**, in anhydrous toluene at 110 °C to give

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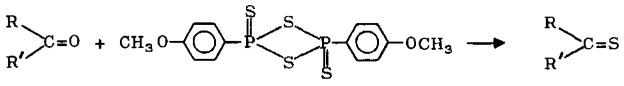
in most cases the corresponding thioketones



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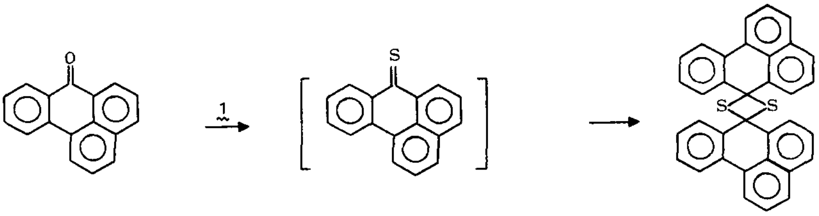
From Table 1 it is seen that the yields are usually quite high and that substituents like Br, NO_2, and $N(CH_3)_2$ do not lead to side-products (tertiary amines and 1 are known to produce betaines[12]). In the case of Michler's ketone no reaction was observed at the dimethylamino groups, probably because of delocalization of the lone-pair electrons of the nitrogen atoms or for steric reasons. It might be emphasized that this method for the preparation of Michler's thioketone is much more convenient than the published hazardous procedure: thiolyses of Michler's ketone in anhydrous HF.[13] To our knowledge thiobenzoylpyridines are unknown. We have been able to prepare the 3-isomer in low yields. Both 2- and 4-benzoylpyridine, when reacted with 1, did not produce thioketones as final products.

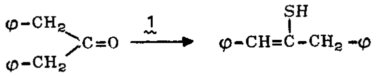
Also the reaction of 1 with benzanthrone did not give the corresponding thiobenzanthrone as final product but, instead, the dimer was isolated in 91 % yield when the temperature was kept at 55 ℃ (the dimer of thiofluorenone has been described earlier[14]).



(or the other isomer)

Two isomers of the thiobenzanthrone dimer are possible but without a crystallographic determination, no definite conclusion can be reached. The mass spectrum of the dimer gave a molecular ion (*m/e* 492) and cryoscopical molecular weight determination (in 1,2-dibromoethane) gave mol.wt. 503 suggesting the dimeric structure, too. The ^{13}C NMR spectroscopy definitely showed that there was no thiocarbonyl group in the molecule, no shifts being observed in the region 220-270.

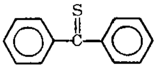
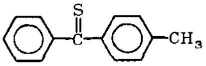
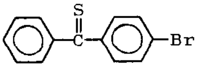
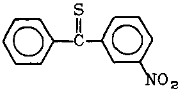
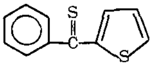
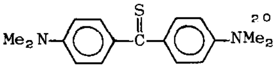
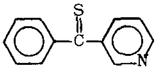
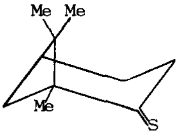
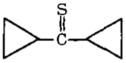
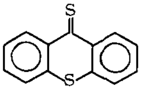
Another unexpected result was obtained when dibenzyl ketone was reacted with 1 and the corresponding enethiol was isolated in 46 % yields.



$$(\varphi\text{-}CH_2)_2C=O \xrightarrow{1} \varphi\text{-}CH=C(SH)\text{-}CH_2\text{-}\varphi$$

TABLE 1. Experimental data for the reaction of ketones with *p*-methoxyphenylthionophosphine sulfide, 1

$$R\text{-}\overset{O}{\overset{\|}{C}}\text{-}R' \xrightarrow{1} R\text{-}\overset{S}{\overset{\|}{C}}\text{-}R'$$

Thioketone	lit)	Yields % (mp) °C	$\delta_{^{13}C=O}$[a]	$\delta_{^{13}C=S}$
	11	98(53)	196.5	238.5
	17	95	196.3	237.3
	18	98	195.5	236.3
		96	194.0	234.8
	19	97	188.0	223.5
	20	92(202-3)	193.7	228.3
 b		32	194.5	235.1
	21	91(142-4)	219.1	271.5
	22	83	210.6	260.6
	11	95(168)	180.1	211.4

[a] ^{13}C NMR are recorded in $CDCl_3$ solutions of the ketones and thioketones (100 mg/mℓ)

[b] Due to instability no elementary analyses were performed

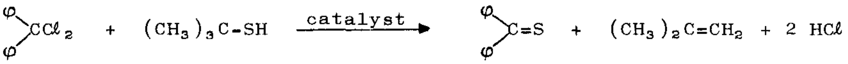
The stereochemistry of the enethiol as well as the scope of this new reaction are unknown but extended work is being made.

As most thioketones are unstable, their characterization was made by help of UV, IR, MS, and especially ^{13}C NMR spectroscopy. In Table 1 the ^{13}C NMR chemical shifts for the carbonyls and thiocarbonyls are recorded, and a least-square linear regression analysis has been performed giving the following equation:

$$\delta_{C=S} = 1.57 \quad \delta_{C=O} - 71.45$$

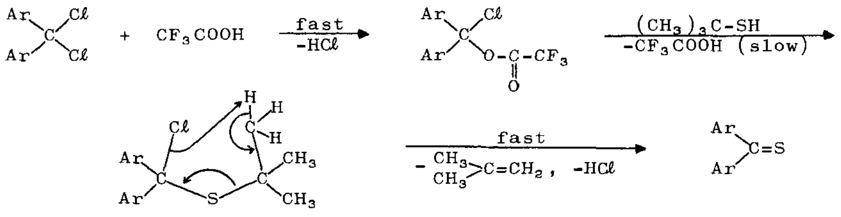
This description of the relation between the chemical shifts of C=S and C=O is quite good, the correlation coefficient being 0.995. The above equation is in fairly good agreement with the equation for different classes of thiocarbonyl compounds calculated by Kalinowski and Kessler.[15]

B. Thioketones from gem-dichlorides. Diphenyldichloromethane, when treated with 2-methyl-2-propanthiol in the presence of a catalyst, such as CF_3COOH or $AlCl_3$, yields the corresponding thioketone:



$$\varphi_2CCl_2 + (CH_3)_3C\text{-}SH \xrightarrow{\text{catalyst}} \varphi_2C{=}S + (CH_3)_2C{=}CH_2 + 2\,HCl$$

Thioxanthion was prepared in the same way, too. Without a catalyst no reaction occurred, and of the catalysts employed, trifluoroacetic acid was the most efficient. Furthermore, the yields of thioketone were strongly dependent on the solvent in which the reaction was run, and good yields were obtained only when CS_2 was used as solvent. As kinetic measurements, run in CS_2 or benzene and with a constant concentration of CF_3COOH, showed that the reaction was first order with respect to both the gem-dichloride and 2-methyl-2-propanethiol, the following mechanism is suggested:



In this connection attention should be drawn to the work of Schönberg et al. about reactions of gem-dihaloderivatives with thioacetic acid[11] and potassium xanthate.[10]

EXPERIMENTAL

^{1}H NMR spectra were recorded at 60 MHz on a Varian A-60 spectrometer. TMS was used as internal reference standard. The chemical shifts are expressed in δ values. ^{13}C NMR spectra were recorded at 20 MHz on a Varian CFT-20 instrument. TMS was added as internal reference. The mass spectra were recorded on a CEC 21-104 single focusing mass spectrometer operating at 70 eV using direct inlet. UV spectra were obtained on a Perkin-Elmer 402 spectrophotometer or on Spectronic 505 (Bausch & Lomb). Silica gel 60 (Merck) was used for column chromatography. Starting materials were either commercial or prepared by known procedures. Elemental analyses were carried out by NOVO Microanalytical Laboratory, Novo Allé, DK-2880 Bagsværd, supervised by Dr.R.E.Amsler. Mp.s and bp.s are uncorrected. The kinetic measurements on the reaction of diphenyldichloromethane with 2-methyl-2-propanethiol were performed in CS_2 and benzene solution. The formation of thiobenzophenone was followed by UV with help of the characteristic $n\rightarrow\pi^*$ absorption at about 610 nm: ϵ_{max} (610 nm, CS_2) = 211 and ϵ_{max} (608 nm, C_6H_6) = 188.

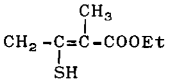
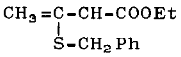
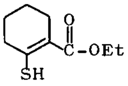
Preparation of **1**. Anisole (270 g) and P_4S_{10} (111 g) were kept for 6 hrs at 150 °C. Toluene (500 mℓ) was added to the solution. After cooling to 20 °C, the precipitate was filtered off and washed with $CHCl_3$ and ether. Yield: 144 g (71 %). Mp. 229 °C (lit.[16] 228-229.5 °C). The title compound should be stored under anhydrous conditions.

General procedure for the reaction of **1** *with ketones*. The ketone (0.01 mole) and **1** (0.006 mole) in 10 mℓ of anhydrous toluene were kept under N_2 at 110 °C until all ketone had been consumed (TLC). Moisture was strictly excluded. The reaction mixture was then allowed to cool to room temp., and subsequent separation on a silica gel column (ether/pet.ether or CH_2Cl_2/pet.ether) gave the thioketone (Table 1). A product with mp. 161 °C (M^+ *m/e* 559) were isolated, too, but in different yields, and with the composition $(CH_3O\text{-}\langle\bigcirc\rangle\text{-}PSO)_3$. Analyses: (Found: C 45.09, H 3.85, P 16.48. Calc. requires: C 45.16, H 3.76, P 16.66 %).

Reaction of **1** *with 1,9-benzanthr-10-one*. 2.30 g (0.01 mole) of 1,9-benzanthr-10-one and 2.4 g (0.006 mole) of **1** were reacted as above but at 55 °C for 4 hrs. Separation (silica gel, CH_2Cl_2) yielded 2.24 g (91 %) of a product with mp. 132 °C (dec.). Analyses: (Found: C 82.96, H 4.00, S 13.04. Calc. requires: C 82.88, H 4.10, S 13.03 %). The molecular weight (cryoscopically in $Br(CH_2)_2Br$): 503. In the mass spectrum (kindly recorded by Dr. J.H.Bowie, The University of Adelaide, Australia), the molecular ion (*m/e* 492) is observed.

1,3-Diphenylpropene-2-thiol. 2.10 g (0.01 mole) of dibenzylketone and 4.8 g (0.012 mole) of **1** in 10 mℓ of anhydrous toluene were reacted as above at 100 °C for 10 hrs. An excess of **1** had to be used to get complete conversion of the ketone into the title compound. Separation on silica gel (ether/light petroleum, 5/95) yielded 1.04 g (46 %) of 1,3-diphenylpropene-2-thiol as a nearly colourless oil (reddish). Analyses: (Found: C 80.00, H 6.11, S 13.80. Calc. requires: C 79.60, H 6.24, S 14.18 %). ^1H NMR ($CDCl_3$): δ 7.0-7.6 (10H,m), 6.53 (1H,s), 3.70 (2H,s), 2.82 (1H,s). ^{13}C NMR ($CDCl_3$): δ 175.7 $(=\underset{SH}{\underset{|}{C}}-)$. IR: 2480 cm^{-1} (weak SH). UV: 230 and 276 nm. MS: (M^+ *m/e*) 226.

In order to get an impression of the ^{13}C chemical shift of the $-\underset{SH}{\underset{|}{C}}-$ group ^{13}C NMR spectra of the following compounds were recorded:

	$\delta(=\underset{SH}{\underset{|}{C}}-)$
 $CH_2=\underset{SH}{C}-\overset{CH_3}{C}H-COOEt$	173.6
 $CH_3=\underset{S-CH_2Ph}{C}-CH-COOEt$	175.8
	169.8

Thiobenzophenone. 47.4 g (0.2 mole) of diphenyldichloromethane, 36.0 g (0.4 mole) of 2-methyl-2-propanethiol) and 6.1 g (0.05 mole) of trifluoroacetic acid, dissolved in 50 mℓ CS_2, were refluxed overnight under N_2 and in the dark. Solvent and excess reagents were distilled off and the crude product distilled at 112 °C/0.2 mmHg. Crude yield: 35.9 g (91 %), mp. 45-48 °C.

Crystallization from light petroleum yields 28.8 g (73 %) of thiobenzophenone, mp. 52-53 °C (lit.[11] 51 °C).

Thioxanthion. 17.1 g (0.08 mole) of thioxanthone and 30.0 g (0.24 mole) of oxalyl chloride were refluxed for 20 hrs.[11] Excess of oxalyl chloride was stripped off (100 °C/0.2 mmHg) and to the crude thioxanthone dichloride were added 14.4 g (0.16 mole) of 2-methyl-2-propanethiol and 1.5 mℓ (0.02 mole) of trifluoroacetic acid, dissolved in 20 mℓ CS_2. The reaction mixture became immediately blue, and evolution of 2-methylpropene started. After refluxing overnight the solvent and excess reagents were distilled off and the crude product washed with ligroin. Yield of crude product: 18 g (98 %). Crystallization from 150 mℓ hot xylene yielded 13.8 g (75 %) of the title compound, mp. 168 °C (lit.[11] 168 °C).

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