

Studies of Fluorinated β -Diketones and Related Compounds. Part 6.[†] Synthesis and Spectroscopic Studies of Some New Fluorinated β -Thio-ketones and their Copper Chelates

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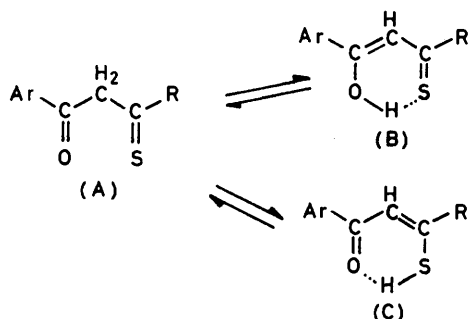
Twelve new fluorinated β -thioxo-ketones have been prepared from the corresponding fluorinated acetophenones and appropriate *O*-alkyl thioesters in the presence of sodamide, and have been characterized as copper chelates. These β -thioxo-ketones exist entirely in the hydrogen-bonded enol form $\text{ArC(OH)=CH}\cdot\text{CSR}$, as evidenced by i.r. and n.m.r. spectra.

THE chemistry of fluorinated β -diketones has found wide application in diverse areas such as g.l.c., solvent extraction, n.m.r. shift reagents, spectral studies, and the polymer industry.¹⁻⁴ The metal β -diketonate system behaves as a sensitive heterocycle with some aromatic character⁵ which is increased in metal β -thioxo-ketonates. Direct electrophilic substitution reactions in such systems have been reported.⁶ Fluorinated β -diketones are useful in solvent extraction of trace metals, and it has been noticed that the volatility of metal chelates increases with the degree of fluorination of the ligand⁷ and on replacing oxygen with sulphur in metal β -diketonates.⁸ β -Thioxo-ketones have received considerable attention in analytical chemistry as superior chelating agents and thiothenoyltrifluoroacetone (STTA) has been used in spectrophotometric determinations.⁹

We now report the synthesis of and enolization studies on twelve new fluorinated β -thioxo-ketones.

RESULTS AND DISCUSSION

β -Thioxo-ketones could exist in any of the forms (A)—(C). There is considerable controversy about their



tautomeric nature. Livingstone *et al.*¹⁰ and other workers^{11,12} favour the enethiol form (C), on the basis of i.r., n.m.r., and mass spectral data. In contrast, Klose

[†] Part 5, K. C. Joshi, V. N. Pathak, and S. Bhargava, *Indian J. Chem.*, in the press.

¹ G. H. Bamford and D. J. Lind, *Proc. Roy. Soc., Ser. A*, 1969, 302; 1967, 145.

² T. N. Kakuuchara, M. Takeaki, T. Fumio, and M. Nira, *Kogyo Kagaku Zasshi*, 1967, **70**, 755.

³ H. P. Smith, Belg. P. 626,901/1963 (*Chem. Abs.*, 1964, **60**, 13419h).

⁴ C. F. Woffard, U.S.P. 3,484,388/1969 (*Chem. Abs.*, 1970, **72**, 448626q).

⁵ K. C. Joshi and V. N. Pathak, *J. C.S. Perkin I*, 1973, 57.

⁶ A. Yokoyama, S. Kawanishi, and H. Tanaka, *Chem. and Pharm. Bull. (Japan)*, 1970, **18**(2), 356.

⁷ M. R. Richardson and R. E. Sievers, *Inorg. Chem.*, 1971, **10**, 498.

et al.^{13,14} favour the enol structure (B) on the basis of n.m.r. data. Belcher *et al.*¹⁵ recently reported that certain compounds exist in the enethiol form (C) whereas others are in the enol form (B).

The i.r. spectra of our fluorinated β -thioxo-ketones show very weak bands in the 3 650—3 540 cm^{-1} region which we attribute to intermolecularly hydrogen-bonded O—H stretching vibrations. The broad and weak bands in the 2 700—2 100 cm^{-1} region are considered to be due to the chelated enol group¹⁶ ($\text{C}=\text{S}\cdots\text{H}-\text{O}-\text{C}=\text{O}$). Bands in 1 625—1 600 and 1 563—1 550 cm^{-1} regions are attributed to $\text{C}\cdots\text{O}$ (perturbed) and $\text{C}\cdots\text{C}$ (perturbed) stretching vibrations, respectively, and the absence of absorption in the carbonyl (saturated, acyclic) region (1 725—1 705 cm^{-1}) indicates that these compounds exist entirely in the hydrogen-bonded enol form (B).¹⁵ This view finds support in the absence of absorption in the conjugated carbonyl region (1 685—1 665 cm^{-1}) and absence of sharp enethiol ($=\text{C}-\text{S}-\text{H}$) absorption in the 2 650—2 550 cm^{-1} region. A very strong band due to overlapping of $\text{C}\cdots\text{S}$ and C—F stretching absorptions is observed in the 1 267—1 225 cm^{-1} region.¹⁵ In addition, two strong bands are also observed due to C—F stretching vibrations in the 1 180—1 011 cm^{-1} region.

Proton n.m.r. data support the above observations. The compounds show $=\text{CH}-$ signals in the δ 7.55—6.79 region and $=\text{C}-\text{O}-\text{H}\cdots\text{S}=\text{C}$ signals in the δ 15.7—13.0 region^{13,15}. There are no methylene proton signals (in the δ 3.29—3.03 region¹⁵) in the spectra of these compounds except for (7) and (9) (which show methylene proton signals in the δ 3.8—3.7 region). The non-appearance of enethiol ($=\text{C}-\text{S}-\text{H}$) proton signals (in the δ 6.87—4.79 region¹⁷) is strong evidence for the absence of form (C).

¹⁹F N.m.r. spectra give signals in the region 30—59.00 p.p.m. upfield from trifluoroacetic acid.

⁸ E. Baeyer, H. P. Muller, and R. E. Sievers, *Analyt. Chem.*, 1971, **43**, 2012.

⁹ T. Honjo and T. Kiba, *Bull. Chem. Soc. Japan*, 1972, **45**, 185.

¹⁰ S. H. H. Chaston, S. E. Livingstone, T. N. Lockyer, V. A. Pickles, and J. S. Shannon, *Austral. J. Chem.*, 1965, **18**, 673.

¹¹ G. Klose, H. Muller, and E. Uhlemann, *Z. Naturforsch.*, 1964, **19b**, 952.

¹² F. Duus and S.-O. Lawesson, *Arkiv. Kemi*, 1968, **29**, 127.

¹³ G. Klose, P. H. Thomas, E. Uhlemann, and J. Maerki, *Tetrahedron*, 1966, **22**, 2695.

¹⁴ K. Arnold, G. Klose, P. H. Thomas, and E. Uhlemann, *Tetrahedron*, 1969, **25**, 2957, 3775.

¹⁵ R. Belcher, W. I. Stephen, I. J. Thomson, and P. C. Uden, *J. Inorg. Nuclear Chem.*, 1972, **34**, 1018.

¹⁶ K. C. Joshi and V. N. Pathak, *Indian J. Chem.*, 1972, **10**, 485.

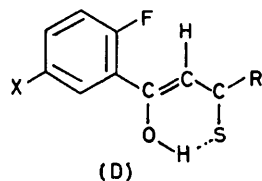
¹⁷ F. Duus, *Tetrahedron*, 1974, **30**, 3753.

In the ^1H n.m.r. spectra, the enolic proton ($\text{O}-\text{H} \cdots \text{S}$) signals are sharp and at low field (δ 15.7—13.0) indicating strong intramolecular and weak intermolecular hydrogen bonding. This is due to the β -thioxo-ketones existing entirely in the enol form (B) and not in the enethiol form (C). The sharper n.m.r. signal for the enolic proton in β -thioxo-ketones, as compared with β -diketones¹⁸ leads to the conclusion that the delocalization of π -electrons in the hydrogen chelated ring is greater in the former case. This is supported by the fact that chemical shifts of methine protons (δ 7.55—6.79), fluorophenyl protons (δ 8.02—7.10), phenyl protons (δ 7.30—7.10), and/or methyl protons (δ 2.60—2.15) are further downfield in the spectra of β -thioxo-ketones than in those of β -diketones.¹⁸

In our series of β -thioxo-ketones chemical shifts of methine and enolic protons are further downfield in the spectra of compounds (2), (4), (6), (8), (10), and (12) (Ar = fluorophenyl, R = phenyl) than in those of compounds (1), (3), (5), (7), (9), and (11) (Ar = fluorophenyl, R = methyl). This can be explained by the deshielding and mesomeric effects of the coplanar phenyl ring.¹⁹

Compounds (5), (6), (11), and (12) exhibit long-range coupling of the methine proton (J_{HF} 0.05—0.08 Hz) with fluorine [see structure (D)].

Assignments of the main i.r. absorption bands of the copper(II) chelates of these β -thioxo-ketones have been made (see Supplementary Publications^{10,20,21}). The absorption peaks for $\text{C}=\text{O}$ (1 600—1 575 cm^{-1}) and $\text{C}=\text{C}$ (1 535—1 475 cm^{-1}) are at lower frequency than those



(D)
 $\text{X}=\text{F}$ or Me , $\text{R}=\text{Me}$ or Ph

1 625—1 600 and 1 563—1 550 cm^{-1} , respectively of the β -thioxo-ketones themselves. These observations are consistent with a conjugated chelate structure and indicate a higher degree of delocalization of π -electrons.

EXPERIMENTAL

^1H N.m.r. spectra were determined at 60, 100, and 220 MHz for solutions in carbon tetrachloride and $[\text{H}^2]\text{chloroform}$ with tetramethylsilane as internal reference. ^{19}F N.m.r. spectra were recorded at 58 MHz with trifluoroacetic acid as external reference. I.r. spectra were determined for KBr pellets. Elemental analyses were performed by the Australian Microanalytical Service, CSIRO, Melbourne, Australia. Analytical and spectral data are available as Supplementary Publication No. SUP 22015 (5 pp.).†

Calculation of Enol Percentages, by the ^1H N.m.r. Method.—

† For details of Supplementary Publications see Notice to Authors No. 7 in *J.C.S. Perkin I*, 1976, Index issue.

¹⁸ K. C. Joshi, V. N. Pathak, and S. Bhargava, *J. Inorg. Nuclear Chem.*, in the press.

¹⁹ A. Yokoyama, S. Kawanishi, and H. Tanaka, *Chem. and Pharm. Bull. (Japan)*, 1970, **18**(2), 363.

²⁰ E. Uhlemann and P. Thomas, *Z. Anorg. Allgem. Chem.*, 1967, **71**, 356.

Enol percentages were calculated by comparing integration values for the enolic proton with those for methyl, methoxy, or aromatic protons.²²

Fluorinated Hydrocarbons.—Fluorobenzene, 2-fluorotoluene, 4-fluorotoluene, 1-chloro-2-fluorobenzene, and 2-fluoroanisole were prepared by Balz-Schiemann reactions²³ from the corresponding amines.

Fluorinated Acetophenones.—Fluorinated acetophenones were prepared according to the method of Buu-Hoi *et al.*²⁴

O-Ethyl Thioesters.—The thioesters RC(S)OEt were prepared from the corresponding imidic esters by the action of hydrogen sulphide.²⁵

Fluorinated β -Thioxo-ketones.—These were prepared by Claisen condensation of fluorinated acetophenones with *O*-ethyl thioesters.²⁶ The fluorinated acetophenone (0.1 mol) was added to a stirred ethereal suspension of sodamide (0.2 mol). After 0.5 h an ethereal solution of the thioester (0.1 mol) was added dropwise with stirring under reflux. The mixture was left overnight and then extracted with cold water. The aqueous solution was neutralised with carbon dioxide to precipitate the fluorinated β -thioxo-ketone, which was recrystallized from ethanol or distilled under reduced pressure. These products each gave a single spot in t.l.c. Physical characteristics are recorded in the Table.

Fluorinated β -thioxo-ketones ($\text{ArCO}\cdot\text{CH}_2\cdot\text{CSR}$) and their copper chelates $[(\text{ArCO}\cdot\text{CH}\cdot\text{CSR})_2\text{Cu}]$ (Ar = substituted phenyl)

No.	Substituent(s) in Ar	R	β -Thioxo-ketone		Chelate	
			M.p. [b.p. ($^{\circ}\text{C}$)]	Yield (%)	M.p. ($^{\circ}\text{C}$)	Yield (%)
(1)	4-F	Me	56	57	130	82
(2)	4-F	Ph	100	67	164	93.6
(3)	4-F, 3-Me	Me	38	61	145	78.5
(4)	4-F, 3-Me	Ph	72	70	155	94.0
(5)	2-F, 5-Me	Me	[105 at 0.5 mmHg]	61.5	86	70.0
(6)	2-F, 5-Me	Ph	35	62	170	71.0
(7)	4-F, 3-Cl	Me	49	60	99	80.0
(8)	4-F, 3-Cl	Ph	81	65	114	86.0
(9)	3-F, 4-OMe	Me	82	51	124	85.0
(10)	3-F, 4-OMe	Ph	130	60	159	93.0
(11)	2,5-F ₂	Me	45	50	125	89.0
(12)	2,5-F ₂	Ph	81	70	175	96.0

Copper(II) β -Thioxo-ketonates.—A hot filtered solution of copper(II) acetate (0.005 mol) in methanol–water (1 : 1) was added to a methanolic solution of a fluorinated β -thioxo-ketone (0.01 mol). The copper chelate was filtered off, air-dried, and recrystallized from benzene–light petroleum (b.p. 40—60 $^{\circ}\text{C}$). All copper(II) chelates gave single spots in t.l.c.

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²¹ S. H. Chaston and S. E. Livingstone, *Austral. J. Chem.*, 1967, **20**, 1065.

²² H. S. Jarrett, M. S. Sadler, and J. N. Shoolery, *J. Chem. Phys.*, 1953, 2092.

²³ G. Balz and G. Schiemann, *Ber.*, 1927, **60**, 1186.

²⁴ N. P. Buu-Hoi and P. Jacquignon, *J. Chem. Soc.*, 1952, 4172; N. P. Buu-Hoi and N. D. Xuong, *ibid.*, 1953, 386; N. P. Buu-Hoi, N. D. Xuong, and B. K. Diep, *ibid.*, 1963, 2784.

²⁵ M. Matsui, *Mem. Coll. Sci. and Eng., Kyoto Univ.*, 1908, **1**, 285 (*Chem. Abs.*, 1909, 2697).

²⁶ E. Uhlemann and H. Muller, *Angew. Chem. Internat. Edn.*, 1965, **4**, 154; E. Uhlemann and P. Thomas, *J. Prakt. chem.*, 1966, **34**, 180.