Oxidation of 4-Chromanones with Thallium(III) Nitrate

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Treatment of 4-chromanones **1a-g** with thallium(III) nitrate in acidic methanol results mainly in dehydrogenation, whereas α-methoxylation and/or Taylor-McKillop rearrangement predominate in trimethyl orthoformate. The mechanistic features of these oxidations are briefly discussed.

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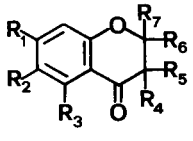
Non degradative oxidation of simple 4-chromanones has been the subject of a limited number of papers. Thus, treatment with lead (IV) acetate has been reported to yield only 3-acetoxy derivatives (1) while dehydrogenation to chromones was accomplished by means of triphenylmethyl perchlorate (2). Attempts with selenium dioxide have been unsuccessful, although flavanones have been smoothly converted to flavones under similar conditions (3).

The present article is concerned with the behavior of a number of 4-chromanones (**1a-g**) with thallium(III) nitrate (TTN), a useful and extremely versatile reagent for the oxidation, *inter alia*, of a variety of enolizable carbonyl compounds (4).

Results and Discussion.

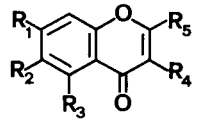
Oxidations were carried out both in methanol containing a little amount of perchloric acid (5) and in trimethyl orthoformate (TMOF) at room temperature or, if exceedingly slow, at reflux. A 25-50% molar excess of TTN was required to ensure completion of the reaction.

The major products of the treatment of **1a-g** in acidic methanol were invariably the corresponding chromones **2a-g** (27-76% yield). Low amounts (≤10% yield) of the 3-methoxy-4-chromanones **1h-k** were obtained starting from **1a**, **b**, **c** and **1g**, respectively. Other identified by-products were **4** (from **1b**), **2h** and **5** (from **1d**), **2i** (from **1f**) and **11** and **1m** (from **1g**). In no case, were we able to isolate in methanol ring-contracted products.



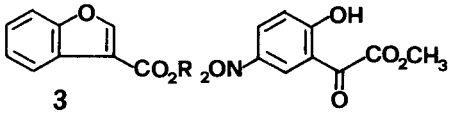
1

a: R_1= R_2= R_3= R_4= R_5= R_6= R_7= H
b: R_1= R_3= R_4= R_5= R_6= R_7= H; R_2= NO_2
c: R_1= R_3= OCH_3; R_2= R_4= R_5= R_6= R_7= H
d: R_1= R_3= R_4= R_5= R_6= H; R_2= Cl; R_7= CH_3
e: R_1= R_3= R_6= R_7= CH_3; R_2= R_4= R_5= H
f: R_1= R_2= R_3= R_4= R_5= H; R_6= R_7= CH_3
g: R_1= R_3= R_4= R_6= R_7= H; R_2= R_5= CH_3
h: R_1= R_2= R_3= R_4= R_6= R_7= H; R_5= OCH_3
i: R_1= R_3= R_4= R_6= R_7= H; R_2= NO_2; R_5= OCH_3
j: R_1= R_3= R_5= OCH_3; R_2= R_4= R_6= R_7= H
k: R_1= R_3= R_6= R_7= H; R_2= R_4= CH_3; R_5= OCH_3
l: R_1= R_3= R_6= R_7= H; R_2= R_4= CH_3; R_5= ONO_2
m: R_1= R_3= R_6= R_7= H; R_2= R_4= CH_3; R_5= OH
n: R_1= R_2= R_3= R_4= R_6= R_7= H; R_5= OH



2

a: R_1= R_2= R_3= R_4= R_5= H
b: R_1= R_3= R_4= R_5= H; R_2= NO_2
c: R_1= R_3= OCH_3; R_2= R_4= R_5= H
d: R_1= R_3= R_4= H; R_2= Cl; R_5= CH_3
e: R_1= R_3= R_4= R_5= CH_3; R_2= H
f: R_1= R_2= R_3= H; R_4= R_5= CH_3
g: R_1= R_3= R_5= H; R_2= R_4= CH_3
h: R_1= R_3= R_4= H; R_2= Cl; R_5= CH_2OCH_3
i: R_1= R_2= R_3= H; R_4= CH_3; R_5= CH_2OCH_3



3

a: R= CH_3
b: R= H

4

Compounds **1a** and **1b** again underwent dehydrogenation and α-methoxylation when treated with TTN in TMOF, but the second pathway was now largely preferred. A substantial amount (23% yield) of methyl benzofuran-3-carboxylate (**3a**) was also obtained in the case of **1a**. Compounds **1c** and **1d** afforded very complex reaction mixtures which were not further examined. The oxidation of **1e, f, g** led mainly (**1g** gave also **1k** as a by-product) or exclusively to the esters **6a, b, c**. Electrophilic aromatic thallation (6) was suspected to overlap significantly to the oxidation of **1e** in TMOF. Treatment of the polar material accompanying **6a** (50% in weight) with hydrazine (7) regenerated in fact more **6a**.

All the new compounds isolated in the above oxidations were identified from their analytical and spectral data which are reported in Tables 1 and 2.

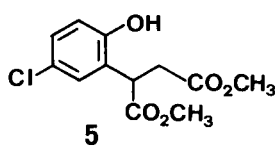
The structures **1h** and **3a** were further confirmed by comparison with samples obtained from **1n** (8) and **3b** (9) with diazomethane. Nitration of **1h** gave **1i** together with the 6,8-dinitro derivative **7**. Reduction of **6a** with lithium

Table 1

Analytical Data of New Compounds

Compound No.	Mp °C (Solvent)	Formula (Molecular Weight)		Analysis Calcd. (Found) C	H	N	Cl
1h	oil	$C_{10}H_{10}O_3$	(178.2)	67.40	5.66		
				(67.52)	(5.73)		
1i	105-106 (benzene/hexane)	$C_{10}H_9NO_5$	(223.05)	53.81	4.06	6.28	
				(53.91)	(4.15)	(6.13)	
1j	101-102 (ether)	$C_{12}H_{14}O_5$	(238.2)	60.50	5.92		
				(60.49)	(5.99)		
1k	oil	$C_{12}H_{14}O_3$	(206.2)	69.88	6.84		
				(69.67)	(6.76)		
1l	107-108 (hexane)	$C_{11}H_{11}NO_5$	(237.2)	55.69	4.67	5.91	
				(55.75)	(4.77)	(5.83)	
1m	oil	$C_{11}H_{12}O_3$	(192.2)	68.73	6.29		
				(68.76)	(6.39)		
2h	82-83 (hexane)	$C_{11}H_9ClO_3$	(224.6)	58.81	4.04		15.78
				(58.75)	(4.13)		(15.56)
2i	37-38 (hexane)	$C_{12}H_{12}O_3$	(204.2)	70.57	5.92		
				(70.45)	(5.96)		
3a	oil	$C_{10}H_8O_3$	(176.2)	68.18	4.58		
				(68.12)	(4.76)		
4	113-115 dec (carbon-tetrachloride)	$C_9H_7NO_6$	(225.2)	48.01	3.13	6.22	
				(47.87)	(3.06)	(6.20)	
5	90-91 (hexane)	$C_{12}H_{13}ClO_5$	(272.7)	52.86	4.81		13.00
				(52.75)	(4.87)		(13.07)
6a	43-44 (ethanol/water)	$C_{14}H_{18}O_3$	(234.3)	71.77	7.74		
				(71.60)	(7.68)		
6b	oil	$C_{12}H_{14}O_3$	(206.2)	69.88	6.84		
				(69.70)	(6.80)		
6c	oil	$C_{12}H_{14}O_3$	(206.2)	69.88	6.84		
				(69.83)	(6.89)		
7	153-156 (benzene)	$C_{10}H_8N_2O_7$	(268.2)	44.78	3.01	10.45	
				(44.82)	(2.98)	(10.35)	
8	oil	$C_{13}H_{18}O_2$	(206.3)	75.69	8.80		
				(75.44)	(8.78)		

aluminum hydride afforded the hydroxymethyl compound **8**.



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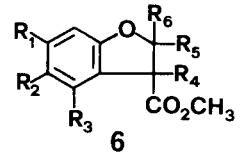

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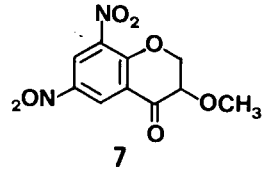
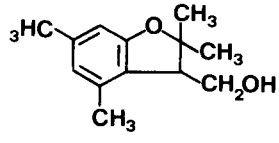


7

a: R_1= R_3= R_5= R_6= CH_3; R_2= R_4= H
b: R_1= R_2= R_3= R_4= H; R_5= R_6= CH_3
c: R_1= R_3= R_5= R_6= H; R_2= R_4= CH_3
d: R_1= R_2= R_3= R_4= R_5= R_6= H



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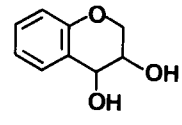

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Table 2

Spectral Data of New Compounds

Compound No.	IR, cm^{-1} (Chloroform) C=O	other	^{1}H-NMR, δ (Deuteriochloroform)	MS, m/e (rel intensity)		
1h	1705		3.55 (3H, s, OCH_3), 3.77 (1H, t, J = 6 Hz, 3-H), 4.39 (2H, d, J = 6 Hz, CH_2), 6.86-7.90 (4H, aromatics)	178 (8),	148 (70),	120 (100)
1i	1700		3.57 (3H, s, OCH_3), 3.96 (1H, m, 3-H), 4.62 (2H, m, CH_2), 7.07-8.84 (3H, aromatics)	193 (100),	165 (37)	
1j	1675		3.56 (3H, s, 3-OCH_3), 3.73 (1H, m, 3-H), 3.82 and 3.88 (6H, 2s, 5-and 7-OCH_3), 4.43 (2H, m, CH_2), 6.08 (2H, br, aromatics)	238 (2),	208 (27),	180 (100)
1k	1685		1.33 (3H, s, 3-CH_3), 2.30 (3H, s, 6-CH_3), 3.29 (3H, s, OCH_3), 4.13 and 4.47 (2H, ABq, J = 12 Hz, CH_2), 6.84-7.77 (3H, aromatics)	206 (12), 134 (100)	191 (14),	176 (37),
1l	1705	1655(ONO_2)	1.63 (3H, s, 3-CH_3), 2.32 (3H, s, 6-CH_3), 4.27 and 4.96 (2H, ABq, J = 11 Hz, CH_2), 6.87-7.78 (3H, aromatics)	237 (11),	191 (91),	135 (100)
1m	1690	3500(OH)	1.42 (3H, s, 3-CH_3), 2.28 (3H, s, 6-CH_3), 3.80 (1H, s, OH), 4.16 and 4.27 (2H, ABq, J = 11.5 Hz, CH_2), 6.84-7.71 (3H, aromatics)	192 (40),	177 (7),	134 (100)
2h	1655		3.49 (3H, s, OCH_3), 4.37 (2H, s, CH_2OCH_3), 6.43 (1H, s, 3-H), 7.34-8.20 (3H, aromatics)	224 (87),	194 (100),	165 (67)
2i	1635		2.10 (3H, s, CH_3), 3.45 (3H, s, OCH_3), 4.48 (2H, s, CH_2 OCH_3), 7.29-8.31 (4H, aromatics)	204 (35),	189 (100),	174 (78)
3a	1725		3.88 (3H, s, CO_2CH_3), 7.23-8.10 (4H, aromatics), 8.17 (1H, s, 2-H)	176 (55),	145 (100)	
4	1750 1660	3100(OH)	4.08 (3H, s, CO_2CH_3), 7.15-8.90 (3H, aromatics), 11.85 (1H, br, OH)	225 (7),	166 (100)	
5	1740	3300(OH)	2.73, 3.27 and 4.29 (3H, ABX system, J_{AB} = 18 Hz, J_{AX} = 7 Hz, J_{BX} = 9 Hz, -CH-CH_2-), 3.70 and 3,74 (6H, 2s, CO_2CH_3), 6.78-7.27 (4H, aromatics and OH)	272 (100),	240 (37)	
6a	1735 1720		1.42 and 1.47 (6H, 2s, 2-CH_3), 2.09 and 2.25 (6H, 2s, 4-and 6-CH_3), 3.71 (3H, s, CO_2CH_3), 3.89 (1H, s, 3-H), 6.47 and 6.52 (2H, 2s, aromatics)	193 (100),	165 (32)	
6b	1740		1.34 and 1.58 (6H, 2s, 2-CH_3), 3.71 (3H, s, CO_2CH_3), 4.04 (1H, s, 3-H), 6.72-7.27 (4H, aromatics)	206 (82), 147 (100)	174 (15),	159 (21),
6c	1735		1.58 (3H, s, 3-CH_3), 2.28 (3H, s, 5-CH_3), 3.73 (3H, s, CO_2CH_3), 4.22 and 5.04 (ABq, J = 9 Hz, CH_2), 6.65-7.16 (3H, aromatics)	206 (20),	147 (100)	
7	1715		3.58 (3H, s, OCH_3), 4.07 (1H, m, 3-H), 4.86 (2H, m, CH_2), 9.04 (2H, ABq, J_{meta} = 3 Hz, aromatics)	238 (75)		
8		3460(OH)	1.30 and 1.56 (6H, 2s, 2-CH_3), 2.06 (1H, br, OH), 2.21 (6H, s, 4-and 6-CH_3), 3.00 (1H, t, J = 6 Hz, 3-H), 3.75 (2H, d, J = 6 Hz, CH_2OH), 6.42 and 6.47 (2H, 2s, aromatics)	206 (28),	175 (100),	147 (35)

Table 3

Reaction of 4-Chromanones **1a-g** with TTN

4-Chromanone	Products (% yield) (a)											
	Dehydrogenation			α-Methoxylation			Ring Contraction			Other		
		MeOH	TMOF		MeOH	TMOF		MeOH	TMOF		MeOH	TMOF
1a	**2a**	(76)	(11)	**1h**	(7)	(57)	**3a**		(23)			
1b	**2b**	(27)	(17)	**1i**	(7)	(56)				**4**	(13)	
1c	**2c**	(65)		**1j**	(10)							
1d	**2d**	(59)								**2h**	(15)	
										5	(6)	
1e	**2e**	(72)					**6a**		(61) (b)			
1f	**2f**	(64)					**6b**		(58)	**2i**	(11)	
1g	**2g**	(48)		**1k**	(10)	(12)	**6c**		(57)	**1l**	(17)	
										1m	(7)	

(a) Yield calculated from weight of pure chromatographic fractions. (b) After treatment with hydrazine (see Experimental).

The results of the oxidations are summarized in Table 3. Oxidative rearrangement and/or α-methoxylation are well known to occur in the treatment of enolizable carbonyl compounds with TTN in methanol or TMOF and detailed mechanisms for these transformations are available (4).

Consideration of the same type of mechanisms for our oxidations is thus straightforward.

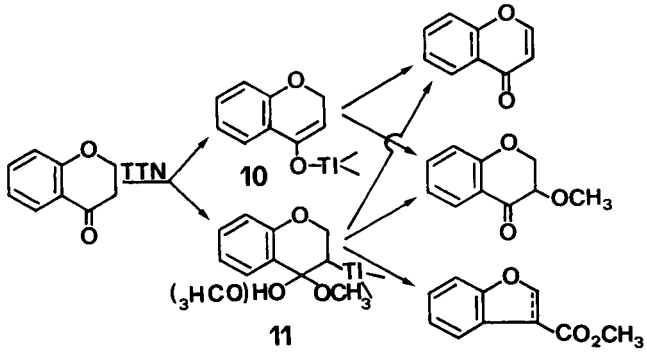
That certain TTN-mediated oxidations of both saturated and α,β-unsaturated ketones may take a different course in TMOF as compared with methanol is known as well and is ascribed to their initial conversion to enol ethers and ketals, respectively (4g, 4i, 10).

This interpretation has been tested by the independent preparation of methyl enol ethers and dimethyl ketals and their subsequent reaction with TTN (4 g, 10a, 10b).

The factors responsible for the difference in products obtained from saturated ketones and their enol ether derivatives have, however, not yet been defined.

We only suggest that an important role in determining the marked solvent effect observed by us could be played by the intervention in methanol of the thallium enolate **10** in alternative to the generally accepted α-thallium adduct **11** (Scheme 1).

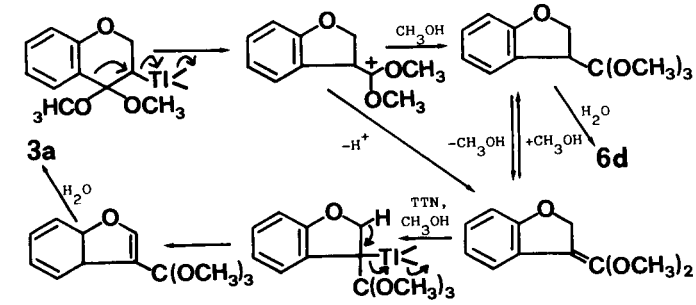
Scheme I



The prevalent dehydrogenation recorded in methanol is unprecedented as concerns TTN oxidations and may be conceivably related with the aromatic stabilization of the resultant chromones and their relative inertia toward further oxidation. 1-Tetralone, for instance, has been converted under similar conditions to an intractable mixture (11).

The isolation of **3a** from **1a** in TMOF is somewhat puzzling since **1h**, **2a** and **6d** (12) are not intermediates in this conversion, all being recovered unchanged under the reaction conditions. A tentative explanation is that **3a** is the result of two successive methoxythallations according to the sequence proposed by Taylor an McKillop to account for the formation of methyl α-methoxyphenylacetate from acetophenone in TMOF and involving the intermediacy of a ketene dimethylketal (10c) (Scheme 2).

Scheme 2

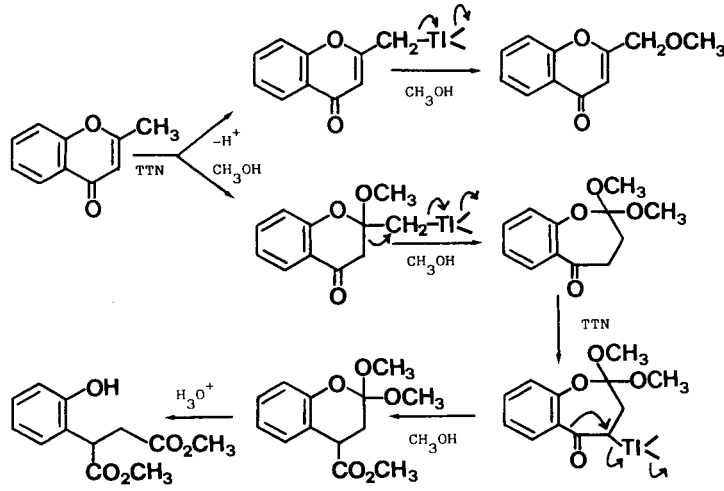


Different from lead(IV) acetate oxidations (1) where no alkyl shift is observed in the chomanone series, even with **1f**, both **2e** and **2f** result evidently from a Wagner-Meerwein rearrangement. On the other hand, no 3-methylchromone is obtained from **1d** where the stereochemistry of the thallium adduct is probably unfavorable to the methyl migration.

2-Methylchromones are prone to further oxidation by TTN. A blank experiment confirmed in fact that **2h** and **5** arise from **2d**.

A number of plausible alternate pathways can be envisioned for these conversions. The following (Scheme 3) finds its analogy in the oxidation of methylenecycloalkanes (4i, 13).

Scheme 3



Alkyl substitution of the hetero ring invariably depresses α-methoxylation, apparently because of steric reasons.

The effect of aromatic substitutions is more difficult to assess because of paucity of data in TMOF. Electron-withdrawing substituents seem, and this is reasonable, to disfavor aryl migration (compare for example **1a** and **1b** in TMOF). It is, however, a little surprising that **1c**, which would be expected on the basis of migratory aptitudes to give a clean oxidative-rearrangement, is instead converted to an intractable mixture.

EXPERIMENTAL

Melting points were determined with Kofler apparatus and are uncorrected. Infrared spectra were recorded on a Perkin-Elmer 521 spectrophotometer. ^{1}H-nmr spectra were measured on a Varian EM-390 spectrometer. Mass spectra were obtained on a Hewlett-Packard 5930 A instrument. Merck silica gel 60 (230-400 mesh ASTM) was used for column chromatographies. Light petroleum refers to the fraction bp 40-60°.

General Procedure for Oxidation of 4-Chromanones with TTN.

A solution of the 4-chromanone (1 mmole) and TTN (1.25 or 1.50 mmoles) in 3 ml of methanol containing 0.3 ml of 70% perchloric acid (or in 3 ml of TMOF) was stirred at room temperature (or at reflux) for the appropriate period (tlc monitoring). Thallium(I) nitrate was removed by filtration. The filtrate was concentrated at room temperature under *vacuo*, diluted with water and extracted twice with ether (dichloromethane for **1c**). The organic layers were washed with water until neutral, dried (sodium sulfate) and evaporated.

Oxidation of **1a** in Acidic Methanol.

Compound **1a** (14) (740 mg, 5 mmoles) and TTN (2.78 g, 6.25 mmoles) in methanol (15 ml) and perchloric acid (1.5 ml) reacted 5 hours at room temperature. The residue (725 mg) was chromatographed on silica gel (22 g). Elution with light petroleum-ether 8:2 gave **1h** (59 mg). Elution with light petroleum-ether 1:1 gave **2a** (552 mg), mp 55-56° (from hexane) [literature (15) mp 58-60°].

Oxidation of **1a** in TMOF.

Compound **1a** (740 mg, 5 mmoles) and TTN (2.78 g, 6.25 mmoles) in TMOF (15 ml) gave after 6 hours at room temperature a residue of 820 mg which was chromatographed on silica gel (25 g). Elution with light petroleum-ether 8:2 gave **3a** (203 mg), identical with a sample obtained by esterification of **3b** (7) with ethereal diazomethane, followed by **1h** (508 mg). Elution with light petroleum-ether 1:1 gave **2a** (82 mg).

3-Hydroxy-4-chromanone (**1n**) (8).

Compound **1n** has been previously obtained as by-product (6% yield) in the treatment of 2'-hydroxyacrylophenone with alcaline hydrogen peroxide (8). In our hands, the above procedure failed, however, to afford any **1n**. The following route was therefore devised.

A solution of *cis*-3,4-chromandiol (**9**) (16) (103 mg, 0.62 mmole) and 2,3-dichloro-5,6-dicyanobenzoquinone (141 mg, 0.62 mmole) in dioxane (4 ml) was stirred at room temperature for 24 hours. The hydroquinone precipitated was removed by filtration, the filtrate was evaporated to dryness and the residue was eluted with dichloromethane through a column of silica gel (5 g) to give 73 mg (72% yield) of **1n**, mp 58-59° (from ether) [literature (8) mp 57-58°].

Methylation of **1n**.

A mixture of **1n** (71 mg) and silica gel (100 mg) (17) in 2 ml of ether was saturated with gaseous diazomethane at 0-5° with stirring and left overnight in a refrigerator. The residue (71 mg) from filtration and evaporation of ethereal solution was chromatographed on silica gel (2 g, elution with benzene) to give **1h** (17 mg) followed by unreacted **1n** (35 mg).

Oxidation of **1b** in Acidic Methanol.

Compound **1b** (18) (431 mg, 2.23 mmoles) and TTN (1.49 g, 3.36 mmoles) in methanol (6.7 ml) containing perchloric acid (0.67 ml) were refluxed for 7 hours. The residue (473 mg) was chromatographed on silica gel (24 g). Elution with dichloromethane-light petroleum 1.5:1 gave **4** (65 mg) and **1i** (36 mg). Elution with dichloromethane gave **2b** (116 mg), mp 172-173° (from benzene) [literature (19) mp 173-175°].

Oxidation of **1b** in TMOF.

Compound **1b** (772 mg, 4 mmoles) and TTN (2.22 g, 5 mmoles) in TMOF (12 ml) for 45 hours at room temperature gave a residue (900 mg) whose nmr spectrum showed three different methoxy singlets in 1:1:1 ratio and which were attributed to the dimethylketal of **1i**. The deketalization procedure of Conia (20) was thus followed and the new residue (807 mg) was chromatographed on silica gel (24 g) to afford **1i** (496 mg) from dichloromethane-light petroleum 1.5:1 and **2b** (129 mg) from dichloromethane.

Nitration of **1h**.

Compound **1h** (300 mg) in concentrated sulfuric acid (0.5 ml) was treated at 0° with a mixture of fuming nitric acid (0.1 ml) and concentrated sulfuric acid (0.3 ml), then allowed to stand 5 hours at room temperature. Dilution with ice-cold water was followed by ether extraction. The ethereal layer was washed with water until neutral, dried (sodium sulfate) and evaporated to furnish a residue of 349 mg. Chromatography of this material by preparative tlc (Merck HF_{254} silica gel 0.5 mm thick, several runs from dichloromethane-light petroleum 1:1) gave, in order of decreasing R_f, 40 mg of unreacted **1h**, 97 mg of **1i** and 98 mg of **7**.

Oxidation of **1c** in Acidic Methanol.

Compound **1c** (21) (832 mg, 4 mmoles) was treated with TTN (2.22 g, 5 mmoles) in methanol (12 ml) and perchloric acid (1.2 ml) for 24 hours at room temperature. The residue (819 mg) yielded by chromatography on silica gel (25 g, benzene-ethyl acetate 7:3 as eluant) **1j** (91 mg) followed by **2c** (538 mg), mp 134-135° (from benzene) [literature (22) mp 133-134°].

Oxidation of **1d** in Acidic Methanol.

Compound **1d** (23) (392 mg, 2 mmoles) and TTN (1.33 g, 3 mmoles) in methanol (6 ml) and perchloric acid (0.6 ml) reacted for 24 hours at room temperature. The residue (433 mg) was chromatographed on silica gel (13 g). Elution with dichloromethane-light petroleum 7:3 gave 45 mg (11%) of starting material followed by 228 mg of **2d**, mp 116-118° (from hexane) [literature (24) mp 115-116°]. Elution with dichloromethane-methanol 95:5 gave a mixture of **2h** and **5** (124 mg) which was rechromatographed on neutral Woelm alumina (activity II, 6 g) to give 66 mg of **2h** (from benzene-ethyl acetate 95:5) and 31 mg of **5** (from benzene-ethyl acetate 1:1).

Treatment of **2d** with an equimolar amount of TTN in acidic methanol at room temperature for 24 hours led to the formation of both **2h** and **5** in 18 and 25% yield, respectively (nmr analysis).

Oxidation of **1e** in Acidic Methanol.

Compound **1e** (25) (408 mg, 2 mmoles) and TTN (1.33 g, 3 mmoles) in methanol (6 ml) and perchloric acid (0.6 ml) were refluxed for 3 hours. The residue (290 mg) was constituted by **2e** practically pure, mp 101-102° (from ethanol) [literature (26) mp 100.5°].

Oxidation of **1e** in TMOF.

Compound **1e** (408 mg, 2 mmoles) and TTN (1.33 g, 3 mmoles) in TMOF (6 ml) for 48 hours at room temperature gave a residue of 617 mg which was chromatographed on silica gel (12 g). Elution with dichloromethane gave **6a** (225 mg). Elution with dichloromethane-methanol 95:5 gave 225 mg of a polar material which was believed to be a product of aromatic thallation of **6a**. Treatment of a solution of this material in 2 ml of methanol with 0.5 ml of 85% hydrazine hydrate (7) at room temperature for half of an hour followed by extraction with ether and filtration of the residue (121 mg) through silica gel (3 g) with dichloromethane afforded more **6a** (62 mg).

2,3-Dihydro-2,2,4,6-tetramethyl-3-benzofuranmethanol (**8**).

To 125 mg (3.3 mmoles) of lithium aluminium hydride in 3 ml of anhydrous ether was added **6a** (257 mg, 1.1 mmoles) in 1 ml of anhydrous ether. The mixture was stirred at reflux for 1.5 hours, cooled in an ice-bath and excess hydride decomposed by wet ether. Acidification with 2*N* sulfuric acid and ether extraction afforded **8** (208 mg, 92% yield).

Oxidation of **1f** in Acidic Methanol.

Compound **1f** (27) (352 mg, 2 mmoles) and TTN (1.33 g, 3 mmoles) in methanol (6 ml) and perchloric acid (0.6 ml) were refluxed for 2 hours. The residue (285 mg) was chromatographed on silica gel (14 g, elution with benzene-ether 95:5) to give 224 mg of **2f**, mp 92-95° (from ethanol-water) [literature (28) mp 97°] and 43 mg of **2i**.

Oxidation of **1f** in TMOF.

Compound **1f** (176 mg, 1 mmole) and 555 mg (1.25 mmoles) of TTN in 3 ml of TMOF were stirred at room temperature for 24 hours. The residue (151 mg) was chromatographed on silica gel (4.5 g) with benzene-hexane 7:3 to give 120 mg of **6b** and 10 mg (6%) of starting material.

Oxidation of **1g** in Acidic Methanol.

Compound **1g** (29) (264 mg, 1.5 mmoles) and TTN (831 mg, 2.25 mmoles) in methanol (4.5 ml) and perchoric acid (0.45 ml) are refluxed for 2.5 hours. The residue (283 mg) was chromatographed on silica gel (9g). Elution with benzene-hexane 7:3 gave 61 mg of **1l** followed by 12 mg (5%) of starting material. Elution with benzene gave 30 mg of **1k** followed by a mixture of **1m** and **2g** (150 mg). Rechromatography on neutral Woelm alumina (activity II, 12 g) and elution with benzene gave 125 mg of **2g**, mp 59.5-60° (from light petroleum) [literature (29,30) mp 61-62°]. Elution with ether gave 21 mg of **1m**.

Oxidation of **1g** in TMOF.

Compound **1g** (352 mg, 2 mmoles) and TTN (1.10 g, 2.5 mmoles) in TMOF (6 ml) for 48 hours at room temperature gave a residue of 339 mg. Chromatography on silica gel (10 g, elution with benzene-hexane 7:3) afforded 235 mg of **6c** and 51 mg of **1k**.

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