294. The Conversion of α-Hydroxythioacetals to Functionalized Ketene Thioacetals[1])

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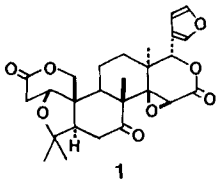
Summary

The conversion of α-hydroxythioacetals to ketene thioacetals possessing an unprotected carbonyl function is described. Besides the intrinsic utility of this transformation it is of interest to recognize that ketene thioacetals are protected carboxyl groups.

Introduction. – During studies directed towards the partial synthesis of limonin (**1**) [1], the triterpenoid bitter principle of citrus fruits, we examined the oxidative fragmentation of α-hydroxythioacetals with lead (IV) acetate (LTA).



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While our studies were in progress a communication by *Trost & Hiroi* [2] appeared, in which they described the oxidative *seco* rearrangement with LTA of α-hydroxythioacetals **i** to α-alkylthio-carbothioates **vii**, and in which they proposed an admittedly speculative mechanism *(Scheme 1)*.

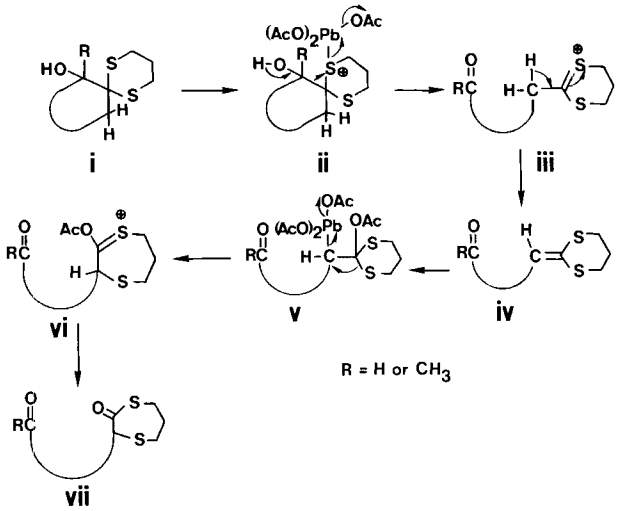
We have oxidized steroidic and also simple aliphatic and alicyclic α-hydroxythioacetals, and found that the ketene thioacetals **iv** *(Scheme 1)* postulated by *Trost & Hiroi* as an intermediate can be isolated. As a consequence, this oxidative fragmentation reaction provides a direct approach to ketene thioacetals which have an unprotected carbonyl group[2]).

We have continued our studies in this area mindfull of the mechanistic proposal of *Trost & Hiroi* [2]. In general, those ketene thioacetals **iv** which bear a hydrogen atom on the double bond readily give, on further treatment with LTA, the dihetero substituted enolacetates, *e.g.* **16** *(Scheme 3)*. Indeed, the α-alkylthio-carbothioates **vii** *(Scheme 1)* isolated by *Trost & Hiroi* are hydrolysis products of such enol acetates.

[1]) Communicated at the autumn meeting of the Swiss Chemical Society, Berne, Oct. 8, 1977. Part of the Ph.D. thesis ETHZ of *W. L.*, in preparation.

[2]) For alternative approaches to ketene thioacetals, see [7] [8].

Scheme 1



Results. – In *Scheme 2* we summarize the results obtained with steroids **2**, **4**, **6**, and **8**[3]). Treatment with LTA gives the ketene thioacetals cleanly and in excellent yields; the use of excess LTA is without influence[4]). The reaction of compound **8** gives an interesting result: again the ketene thioacetal **9** is formed in good yield (66%); however, **9** has an allenic system. The possibility that this kind of allene formation is a general process is being studied.

In contrast, compound **11** reacts with LTA only slowly and gives but a 16% yield of ketene thioacetal **12**. This appears to be a general phenomenon; when the reacting centers are attached to an unstrained ring the oxidation by LTA occurs slowly. Several other instances of the reluctance of such systems to react with LTA are illustrated by compounds **15** and **18** (s. *Scheme 3* and *Table 2*). With one equivalent of LTA the reaction is sluggish and no ketene thioacetal is isolated. After longer reaction times and using an excess of LTA, small yields of the enol acetate **16** and the carbothioates **17**, and **19**, respectively, can be isolated. With the cyclooctane derivative **20** the oxidation is somewhat faster, but at the best a 21% yield of **21** can be isolated (s. *Table 2*).

In contrast, with the somewhat strained systems **24** and **26**, the reaction with LTA is rapid and yields of ketene thioacetals are excellent, for example, **25** is isolated in 92% yield.

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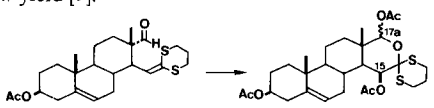
[3]) The synthesis of the α-hydroxythioacetals **4**, **6**, and **8** will be published separately in this journal. The other compounds described here were synthesized according to the procedure given in the exper. part.

[4]) It was found that D-*seco*-steroid ketene thioacetals of type **3** are not oxidized by excess of LTA under standard conditions. When strong conditions are employed the starting material is changed and **14** formed in very low yield [9].



3 **14**

Scheme 2

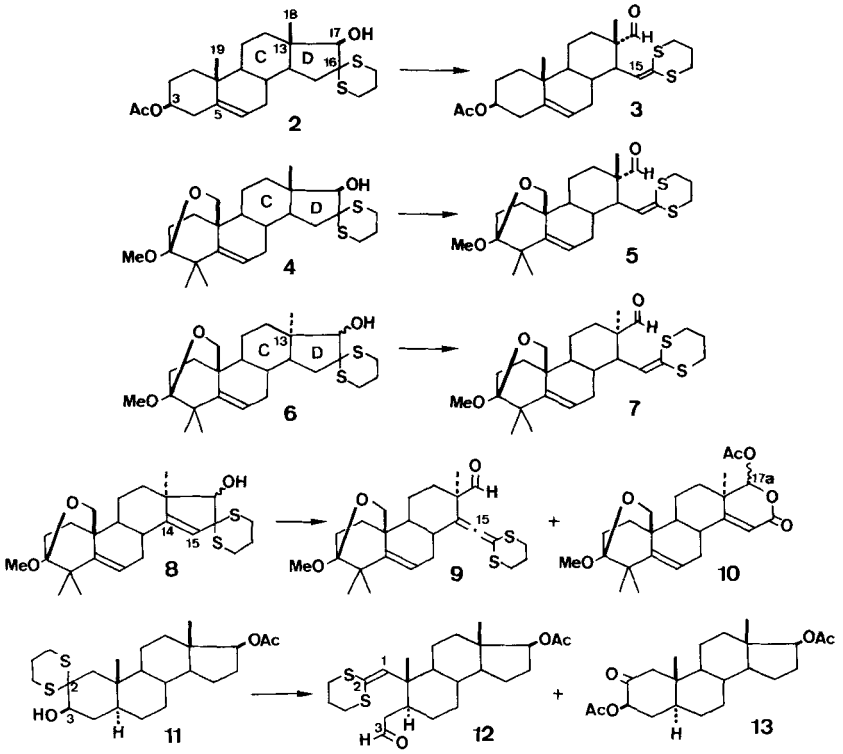


Table 1. *Lead (IV) Acetate* (LTA) *Fragmentation of Steroid Derivatives* (s. *Scheme 2*)

Substrate	Reaction conditions[a])[b])	Products (yield)[c])
2	1 equiv. LTA, Bz, 80°, 20 min	**3** (98%)
	1 equiv. LTA, Acn, 20°, 15 min	**3** (100%)
4	1 equiv. LTA, Bz, 80°, 20 min	**5** (100%)
6	1 equiv. LTA, Bz, 80°, 20 min	**7** (100%)
	1 equiv. LTA, Acn, 20°, 10 min	**7** (100%)
8	1 equiv. LTA, Bz, 20°, 90 min	**9** (70%), **10** (5%), **8** (7%)
	1 equiv. LTA, Bz, 60°, 30 min	**9** (44%), **10** (4%)
	1 equiv. LTA, Bz, 80°, 20 min	**9** (66%), **10** (11%)
11	1 equiv. LTA, Bz, 80°, 30 min	**13** (14%), **11** (30%), **12** (16%)[d])
	2.6 equiv. LTA, Bz, 80°, 20 h	**13** (24%), **11** (18%)
3	2–6 equiv. LTA, Bz, 80°, 19–66 h	**14** (max 3%)[e])

[a]) Reaction conditions are optimized to afford maximum yield of ketene thioacetal by varying solvent and reaction temp.

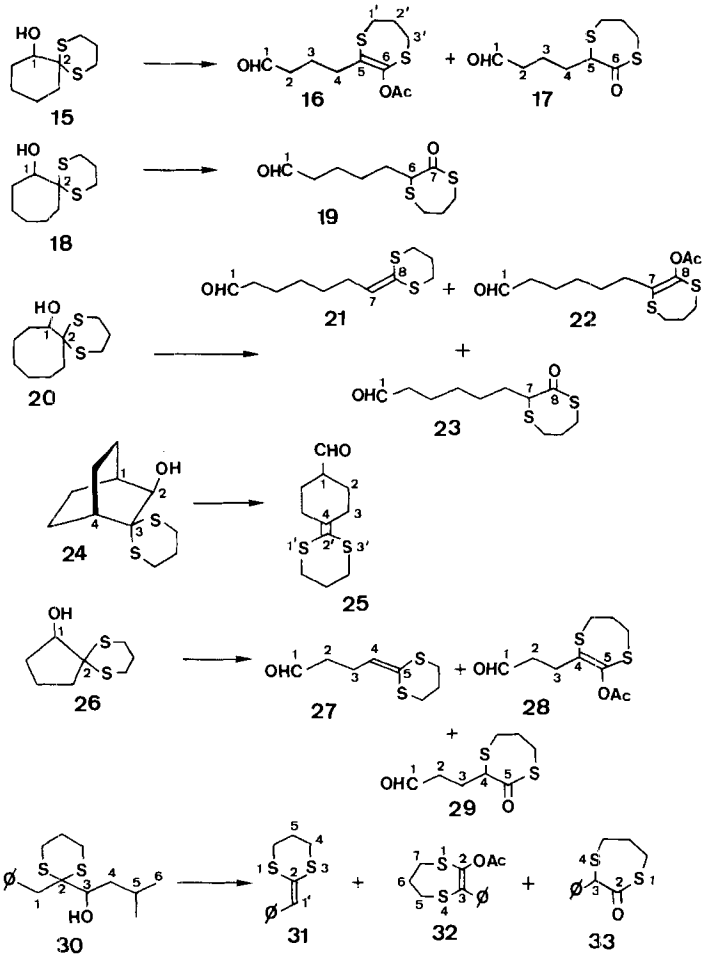
[b]) Bz: benzene, Acn: acetonitrile. Added $CaCO_3$ does not change the reaction significantly.

[c]) Yield practically unchanged by use of excess LTA. Products purified by chromatography or by recrystallization.

[d]) Extremely unstable.

[e]) After 2 h (Bz, 80°) unchanged starting material can be recovered.

Scheme 3



Finally, the open chain compound **30** with 1 equiv. of LTA cleanly produces the ketene thioacetal **31** in 82% yield. This, on further oxidation with 1 equiv. of LTA is converted into **32** (67% yield). Consistent with these results is the treatment of **30** with 2,6 equiv. of LTA giving **32** directly in 71% yield.

Conclusion. – It has been demonstrated that a number of ketene thioacetals possessing unprotected carbonyl groups are readily obtained by LTA oxidation of α-hydroxythioacetals. This has been shown for several ring-D-steroid derivatives and for certain strained simple molecules. In other cases the reaction is slow and capricious, as *Trost & Hiroi* already found. Clearly we were fortunate in that our work was initiated with the steroids **2**, **4**, **6**, and **8**.

It is plausible that the novel LTA oxidative fragmentation corresponds mechanistically to the LTA cleavage of vicinal diols [10]. Attempts to settle this will be published in a following paper.

Table 2. *Lead (IV) Acetate* (LTA) *Fragmentation of α-Hydroxythioacetals* (s. *Scheme 3*)

Substrate	Reaction conditions[a])[b])[c])	Products (yield)[d])
15	1 equiv. LTA, Bz, 50°, 2¾ h	**16** (12%), **17** (12%), **15** (45%)
	1 equiv. LTA, Bz, 80°, 30 min	**16** (18%), **17** (4%), **15** (47%)
	2.6 equiv. LTA, Bz, 50°, 44 h	**16** (6%), **17** (46%)
	2.6 equiv. LTA, Bz, 80°, 70 min	**16** (14%), **17** (38%)
	2.6 equiv. LTA, Bz/HOAc 9:1, 80°, 19 h[e])	**16** (14%), **17** (38%)
	1 equiv. LTA, Acn, 20°, 18 h	**16** (14%), **17** (34%)
18	1 equiv. LTA, Bz, 50°, 2 h	[f]), **18** (40%)
	2.6 equiv. LTA, Bz, 80°, 1½ h	**19** (14%)
	1 equiv. LTA, Acn, 20°, 1½ h	**19** (7%), **18** (40%)
20	1 equiv. LTA, Bz, 80°, 15 min	**21** (21%), **22** (2%)
	2.6 equiv. LTA, Bz, 80°, 4 h	**22** (3%), **23** (30%), **20** (8%)
	2.6 equiv. LTA, Bz, 50°, 30 h	**23** (41%)
24	1 equiv. LTA, Bz, 20°, 2 h	**25** (64%), **24** (13%)
	1 equiv. LTA, Bz, 80°, 10 min	**25** (92%), **24** (6%)
	2.6 equiv. LTA, Bz, 80°, 1 h	**25** (20%)
25	1 equiv. LTA, Bz, 80°, 1 h	**25** (11%)
26	1 equiv. LTA, Bz, 80°, 4 min	**27** (54%), **28** (9%), **26** (12%)
	2.6 equiv. LTA, Bz, 80°, 1½ h	**28** (23%), **29** (13%)
	1 equiv. LTA, Acn, 20°, 10 min	**27** (74%)[g])
30	1 equiv. LTA, Bz, 50°, 2 h	**31** (64%), **32** (11%), **30** (18%)[h])
	1 equiv. LTA, Bz, 80°, 20 min	**31** (82%), **32** (1%), **30** (15%)
	2.6 equiv. LTA, Bz, 50°, 2½ h	**32** (64%), **33** (8%)
	2.6 equiv. LTA, Bz, 80°, 25 min	**31** (6%), **32** (71%), **33** (traces)
31	1 equiv. LTA, Bz, 80°, 25 min	**31** (12%), **32** (67%)

a) $CaCO_3$ (anhyd.) added.

b) LTA was dried by removal of acetic acid at *ca.* 10^{-2} Torr for 12 h before use. Reaction time means the time when all LTA has been consumed (KI/starch test).

c) Bz: benzene, Acn: acetonitrile.

d) Mean yield of chromatographically pure product from several runs. Because of the instability of ketene thioacetals [7] deviation from the mean yield may be considerable. In addition to the pure fractions it is often possible to isolate mixtures of substances showing aldehyde and acetate bands in the IR. spectrum.

e) Without $CaCO_3$.

f) Besides the not isolated very polar substances (starting point on TLC. Silica gel, cyclohexane/ethyl acetate 1:1) no significant apolar product can be isolated.

g) Isolation: the solid was filtered off, the solvent removed by evaporation, and the unstable product distilled *in vacuo*.

h) 3-Methylbutanal was isolated as its 2,4-dinitrophenylhydrazon (80% yield).

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Experimental Part

General remarks. S. [3].

Preparation of α-hydroxythioacetals **d**. The cyclic compounds **2**, **4**, **6**, **8**, **11**, **15**, **18**, **20**, **24**, and **26** were prepared according to *Woodward*'s standard procedure [4] *(Scheme 4)*: **a**→**b** with NaH/HCOOEt/EtOH (kat.) [5], **b**→**c**[5]) with $TsS(CH_2)_3STs$/NaOAc/EtOH [4], and **c**→**d** with (*iso*-Bu)$_2$AlH/toluene or $NaBH_4$/MeOH (s. below).

5) Products **c** were purified by chromatography on silica gel. The analytical data were in accord with the proposed structures.

Scheme 4

The aliphatic α-hydroxythioacetal **30** was prepared according to the *Corey-Seebach* Li-dithian procedure [6] (*Scheme 4*, **e** → **30**).

Reduction **c** → **d**. a) 1 mmol of α-trimethylenedithio-ketone **c** dissolved in about 10 ml of methanol (sparingly soluble ketones were dissolved by addition of about 5–10 ml of dichlormethane) was treated at RT. with 20 mol-equiv. of $NaBH_4$ dissolved in about 2 ml of water. After 1 h the solution was poured into ice/dilute hydrochloric acid and extracted with ether or ethyl acetate. If necessary the product was purified by chromatography on silica gel.

b) Ketones with base labile protecting groups (*e.g.* acetoxy groups) were reduced with $LiBH_4$ in dimethoxyethane (DME) at 0°. 0,5 mmol of ketone were dissolved in 15 ml of DME and 2 ml of THF, cooled to 0° and then treated with 20 mol-equiv. of $LiBH_4$. After 20 min the mixture was poured into ice-cold dilute HCl-solution and extracted with ether or ethyl acetate.

c) Strongly hindered ketones, *e.g.* the starting materials of **4** and **6**, respectively, were reduced with diisobutylaluminium hydride (DIBAH). 1 mmol of ketone was dissolved in 10 ml of toluene and cooled to −60°. After treatment with 10 mol-equiv. of a *ca.* 1M DIBAH-solution in toluene the mixture was stirred for 30 min at −60°. Excess of DIBAH was destroyed by addition of a conc. K, Na-tartrate-solution and the product extracted with ether or ethyl acetate. Analytical data.

3β-Acetoxy-16,16-trimethylendithio-17β-hydroxy-Δ⁵-androstene (**2**). M.p. 194–195°, $[\alpha]_D = -58°$ (0.79). – UV.: 225 (800), 250 (900), 330 (90). – IR.: 3600*w*, 2855, 1726, 905. – ^{1}H-NMR.: 0.85 (*s*, $H_3C(18)$); 1.02 (*s*, $H_3C(19)$); 2.03 (*s*, CH_3COO); 2.55 (*d*, $J = 10$, HO–C(17), exchangeable with D_2O); 2.90 and 3.30 (2*m*, $2\,CH_2S$); 3.83 (*d*, $J = 10$, H–C(17), on addn. of $D_2O \rightarrow s$); 4.56 (*m*, H–C(3)); 5.37 (*m*, H–C(6)). – MS.: 436 (M^+, 24), 376 (10), 301 (4), 270 (11), 269 (25), 268 (100), 119 (8), 106 (10), 91 (8), 75, 74, 73.

3α-Methoxy-3,19-oxido-4,4-dimethyl-16,16-trimethylenedithio-17β-hydroxy-Δ⁵-androstene (**4**). M.p. 240–241°, $[\alpha]_D = -32°$ (0.92). – UV.: 217*sh*, 250 (1200), 310 (84). – IR.: 3500 br., 2877, 2840, 1382, 1330, 905, 899, 838. – ^{1}H-NMR.: 0.82 (*s*, $H_3C(18)$); 1.09 and 1.07 (2*s*, $2\,H_3C$–C(4)); 2.55 (*d*, $J = 10$, HO–C(17), exchangeable with D_2O); 2.64–3.40 (*m*, $2\,CH_2S$); 3.28 (*s*, CH_3O); 3.68 (*d*×*d*, $J = 8$, $J' = 2$, H–C(19)); 3.81 (*d*, $J = 10$, on addn. of $D_2O \rightarrow s$, H–C(17)); 3.94 (*d*, $J = 8$, H–C(19)); 5.54 (*d*×*d*, $J = 7$, $J' = 3$, H–C(6)). – ^{13}C-NMR.: 149.6 (*s*, C(5)); 116.9 (*d*, C(6)); 101.0 (*s*, C(3)); 91.9 (*d*, C(17)); 70.8 (*t*, C(19)); 56.9 (*s*, C(16)). – MS.: 450 (M^+, 38), 344 (47), 329 (11), 287 (18), 106 (57), 75 (3), 74 (8), 73 (21), 45 (22), 43 (50), 41 (100).

3α-Methoxy-3,19-oxido-4,4-dimethyl-16,16-trimethylenedithio-17ξ-hydroxy-13α-Δ⁵-androstene (**6**). M.p. 189–190°, $[\alpha]_D = -90°$ (0.89). – UV.: 228*sh*, 253 (700), 326 (300). – IR.: 3540 br., 2839, 1380, 1330, 908, 835. – ^{1}H-NMR.: 0.96 (*s*, $H_3C(18)$); 1.10 and 1.07 (2*s*, $2\,H_3C$–C(4)); 2.48 (*d*, $J = 11$, HO–C(17), exchangeable with D_2O); 3.29 (*s*, CH_3O); 2.5–3.58 (br. *m*, $2\,CH_2S$); 3.72 (*d*×*d*, $J = 8$, $J' = 2$) and 3.90 (*d*, $J = 8$, 2 H–C(19)); 4.41 (*d*, $J = 11$, H–C(17), on addn. of $D_2O \rightarrow s$); 5.54 (*d*×*d*, $J = 6$, $J' = 2$, H–C(6)). – ^{13}C-NMR.: 148.9 (*s*, C(5)); 117.2 (*d*, C(6)); 101.4 (*s*, C(3)); 85.3 (*d*, C(17)); 71.1 (*t*, C(19)); 55.8 (*s*, C(16)); 49.3 (*qa*, CH_3O). – MS.: 450 (M^+, 100), 432 (7), 407 (25), 344 (14), 343 (22), 287 (21), 119 (25), 106 (27), 75 (10), 74 (9), 73 (25), 45 (10).

3α-Methoxy-3, 19-oxido-4, 4-dimethyl-16, 16-trimethylenedithio-17ζ-hydroxy-13αΔ⁵,¹⁴-androstadiene (**8**). M.p. 246–247°, $[\alpha]_D = -80°$ (0.76). – UV.: 260 (2800), 330 (100). – IR.: 2870, 2839, 1632, 1381, 1332, 908, 815. – ^{1}H-NMR.: 1.11 and 1.09 (2*s*, $2\,H_3C$–C(4)); 1.20 (*s*, $H_3C(18)$); 2.64 (*d*, $J = 11$, HO–C(17), exchangeable with D_2O); 2.48–3.40 (*m*, $2\,CH_2S$); 3.30 (*s*, CH_3O); 3.60–3.90 (*m*, 2 H–C(19)); 4.20 (*d*, $J = 11$ on addn. of $D_2O \rightarrow s$, H–C(17)); 6.55 (*d*, $J = 2$, H–C(15)); 6.59 (*d*×*d*, $J = 8$, $J' = 2$, H–C(6)). – ^{13}C-NMR.: 153.1 (*s*, C(14)); 150.6 (*s*, C(5)); 125.9 (*d*, C(15)); 118.0 (*d*, C(16)); 101.3 (*s*, C(3)); 93.9 (*d*, C(17)); 69.8 (*t*, C(19)); (*qa*, CH_3O). – MS.: 448 (M^+, 100), 374 (11), 119 (7), 106 (6), 75 (2), 74 (2), 73 (3), 45 (3).

2,2-Trimethylenedithio-3β-hydroxy-17β-acetoxy-5α-androstane (**11**). M.p. 238–239°, $[\alpha]_D = -4°$ (0.75). – UV.: 228*sh*, 240 (1200). – IR.: 3550, 2880, 2865, 1724, 900. – ^{1}H-NMR.: 1.06 and 0.77 (2*s*, $H_3C(18)$ and $H_3C(19)$); 2.00 (*s*, CH_3COO); 2.23 (*d*, $J = 6$, HO–C(3), exchangeable with D_2O); 2.40–3.30

(*m*, 6 H, 2 CH_2S and ?); 3.81 (*d*×*d*×*d*, *J* = 12, $J_{H,OH}$ = 6, *J'* = 4, on addn. of $D_2O \rightarrow$ *d*×*d*, H–C(3)); 4.56 (*d*×*d*, *J* = 9, *J'* = 7, H–C(17)). – ^{13}C-NMR.: 171.1 (*s*, CH_3COO); 82.7 and 82.3 (2*d*, C(3) and C(17)); 56.1 (*s*, C(2)). – MS.: 438 (M^+, 100), 420 (19), 364 (17), 119 (9), 106 (32), 75 (4), 74 (3), 73 (7), 45 (6).

2,2-Trimethylenedithio-cyclohexanol (**15**). M.p. 40,5–41°. – UV.: 227 (760), 246 (1050), 250*sh*. – IR.: 3470 br., 2868, 2840, 913. – ^{1}H-NMR.: 1.20–2.28 (*m*,10 H); 2.59 (*d*, *J* = 2, HO–C(1)); 2.36–3.14 (*m*, 2 CH_2S); 4.00 (*d*×*d*×*d*, *J* = 6, *J'* = 3, $J_{H,OH}$ = 2, H–C(1), on addn. of $D_2O \rightarrow$ *d*×*d*). – ^{13}C-NMR.: 69.5 (*d*, C(1)); 55.6 (*s*, C(2)). – MS.: 204 (M^+, 98), 186 (7), 161 (7), 145 (100), 132 (15), 130 (12), 129 (7), 119 (48), 106 (43), 98 (21), 87 (7), 85 (10), 75 (10), 74 (16), 73 (13), 71 (17), 45 (25).

2,2-Trimethylendithio-cycloheptanol (**18**). Oil (b.p. 120°/0.007 Torr). – UV.: 222*sh*, 248 (1000). – IR.: 3460 br., 2862, 2837, 909. – ^{1}H-NMR.: 1.16–2.36 (*m*, 12 H); 2.79 (*d*, *J* = 2, HO–C(1)); 2.40–3.10 (*m*, 2 CH_2S); 4.06 (*d*×*d*×*d*, *J* = *J'* = 4, $J_{H,OH}$ = 2, H–C(1), on addn. of $D_2O \rightarrow$ *d*×*d*). – ^{13}C-NMR.: 72.7 (*d*, C(1)); 59.3 (*s*, C(2)). – MS.: 218 (M^+, 76), 145 (100), 119 (23), 112 (5), 111 (44), 106 (28), 100 (14), 75 (5), 74 (8), 73 (11), 45 (11).

2,2-Trimethylenedithio-cyclooctanol (**20**). Oil (b.p. 108°/0.01 Torr). – UV.: 224*sh*, 246 (1100), 300 (400). – IR.: 2858, 2838, 910. – ^{1}H-NMR.: 1.20–2.52 (*m*, 14 H); 2.67 (*d*, *J* = 3, HO–C(1)); 2.8–2.96 (*m*, 2 CH_2S); 3.97 (*d*×*d*×*d*, *J* = 8, *J'* = 2, $J_{H,OH}$ = 3, H–C(1), on addn. of $D_2O \rightarrow$ *d*×*d*). – ^{13}C-NMR.: 74.9 (*d*, C(1)); 61.3 (*s*, C(2)). – MS.: 232 (M^+, 26), 157 (12), 147 (11), 145 (100), 125 (78), 119 (90), 114 (10), 106 (50), 95 (25), 87 (11), 81 (16), 75 (8), 74 (10), 73 (17), 45 (14).

3,3-Trimethylenedithio-bicyclo[2.2.2]octan-2-ol (**24**). M.p. 92–93°. – UV.: 224*sh*, 250 (1050). – IR.: 3590, 3430, 2870, 2838, 912. – ^{1}H-NMR.: 1.10–2.29 (br. *m*, 12H); 2.92 (*d*, *J* = 8, HO–C(2), exchangeable with D_2O); 2.45–3.25 (*m*, 2 CH_2S); 3.93 (*d*×*d*, $J_{H,OH}$ = 8, *J'* = 3, H–C(2)). – ^{13}C-NMR.: 77.7 (*d*, C(2)); 59.6 (*s*, C(3)). – MS.: 230 (M^+, 100), 156 (24), 145 (27), 128 (15), 127 (14), 124 (29), 119 (99), 106 (46), 96 (44), 75 (6), 74 (10), 73 (13), 45 (12).

2,2-Trimethylenedithio-cyclopentanol (**26**). Oil (b.p. 30°/0.01 Torr). – UV.: 227*sh*, 247 (840). – IR.: 2860, 2838, 2820, 908. – ^{1}H-NMR.: 1.62–2.40 (*m*, 8 H); 2.72 (*d*, *J* = 1.5, HO–C(1)); 2.48–3.16 (*m*, 2 CH_2S); 4.30 (*d*×*d*, *J* = 4, $J_{H,OH}$ = 1.5, H–C(1), on addn. of $D_2O \rightarrow$ *d*). – ^{13}C-NMR.: 75.0 (*d*, C(1)); 60.8 (*s*, C(2)). – MS.: 190 (M^+, 100), 172 (10), 145 (58), 119 (95), 116 (20), 115 (21), 106 (50), 87 (25), 84 (25), 75 (13), 74 (36), 73 (31), 71 (41), 45 (33).

5-Methyl-1-phenyl-2,2-trimethylenedithio-3-hexanol (**30**). M.p. 72–73°. – UV.: 223*sh*, 242*sh*, 260 (900), 267 (700). – IR.: 3480 br., 2868, 2832, 1602, 1492, 908. – ^{1}H-NMR. (probe temp. 25°): 0.96 and 1.00 (2*d*, *J* = 6, 2 H_3C–C(5)); 1.35–2.10 (*m*, 5 H); 2.34–3.10 (*m*, 2 CH_2S); 2.73 (*d*, *J* = 1, HO–C(3), exchangeable with D_2O); 2.83 and 3.15 (2*d*, each with *J* = 14, 2 H–C(1)); 4.09 (*d*×*d*×*d*, *J* = 5, $J_{H,OH}$ = 2, *J'* = 1.5, H–C(3), on addn. of $D_2O \rightarrow$ *d*×*d*); 7.40–7.19 (*m*, 5 H, arom. H). – ^{13}C-NMR.: 135.9 (*s*); 131.3 (2*d*); 127.4 (2*d*); 126.8 (*d*, arom. C); 70.1 (*d*, C(3)); 59.7 (*s*, C(2)); 40.1 (*t*); 39.2 (*t*, CH_2S). – MS.: 296 (M^+, 4), 211 (11), 209 (100), 205 (21), 119 (12), 107 (16), 105 (14), 91 (27), 77 (6), 75 (7), 74 (3), 73 (11).

General procedure for the lead(IV) acetate (LTA) *fragmentation of α-hydroxythioacetals.* 0,1–1 mmol of *α*-hydroxythioacetal **d** were dissolved in the dry solvent as shown in *Table 1* and *2*, resp. (5–10 ml). $CaCO_3$ (anhyd.) was added and the reaction flask flushed with N_2. After addition of the amount of LTA (dried 12 h *in vacuo*) shown in the *Tables* the mixture was stirred at the temp. for the time indicated. The cooled mixture was poured into an ice-cold dilute $NaHCO_3$-solution and extracted with ether or ethyl acetate. The residue was chromatographed on silica gel (eluents cyclohexane/ethyl acetate 4:1 and 2:1, resp.); distilled or recrystallized products were analyzed. Analytical data.

3β-Acetoxy-16,16-trimethylenedithio-17-oxo-16,17-seco-$\Delta^{5,15}$-*androstadiene* (**3**). M.p. 142°, $[\alpha]_D$ = –50° (1.20). – UV.: 260 (9500). – IR.: 2860, 2835, 2713, 1725, 1580, 910. – ^{1}H-NMR.: 1.02 and 1.07 (2*s*, H_3C(18) and H_3C(19)); 2.03 (*s*, CH_3COO); 2.85 (*m*, 2 CH_2S); 4.60 (*m*, H–C(3)); 5.35 (*m*, H–C(6)); 5.68 (*d*, *J* = 11, H–C(15)); 9.39 (*s*, H–C(17)). – ^{13}C-NMR.: 204.0 (*d*, C(17)); 129.0 (*s*, C(16)); 132.7 (*d*, C(15)); 50.5 (*s*, C(13)). – MS.: 434 (M^+, 5), 132 (100).

3α-Methoxy-3,19-oxido-4,4-dimethyl-16,16-trimethylenedithio-17-oxo-16,17-seco-$\Delta^{5,15}$*-androstadiene* (**5**). M.p. 204–205°, $[\alpha]_D$ = –2° (0.46). – UV.: 220 (endabsorpt.), 260 (6800). – IR.: 2875, 2838, 2718, 1724, 1580, 912. – ^{1}H-NMR.: 1.04 and 1.07 (2*s*, H_3C(18) and 2 H_3C–C(4)); 3.74–3.94 (*m*, 2 CH_2S); 3.28 (*s*, CH_3O); 3.72 (*d*×*d*, *J* = 7, *J'* = 2) and 3.92 (*d*, *J* = 8, 2 H–C(19)); 5.56 (*d*×*d*, *J* = 7, *J'* = 2, H–C(6)); 5.73 (*d*, *J* = 11, H–C(15)); 9.52 (*s*, H–C(17)). – ^{13}C-NMR.: 204.9 (*d*, C(17)); 129.1 (*s*, C(16)); 132.6 (*d*, C(15)); 50.5 (*s*, C(13)). – MS.: 448 (M^+, 15), 420 (4), 288 (16), 201 (20), 132 (100), 74 (5).

3α-Methoxy-3,19-oxido-4,4-dimethyl-16,16-trimethylenedithio-17-oxo-13α-16,17-seco-$\Delta^{5,15}$-*androstadiene* (**7**). M.p. 220–221°, $[\alpha]_D$ = –29° (0.67). – UV.: 220 (endabsorpt.), 258 (9600), 330 (400). – IR.: 2873, 2838, 2715, 2700, 1720, 915, 910. – ^{1}H-NMR.: 1.07 (*s*, H_3C(18) and 2 H_3C–C(4)); 2.75–3.00 (*m*,

2 CH_2S); 3.26 (*s*, CH_3O); 4.65 (*d*×*d*, *J* = 8; *J'* = 3) and 4.83 (*d*, *J* = 8, 2 H–C(19)); 5.53 (*d*×*d*, *J* = 6, *J'* = 2, H–C(6)); 6.11 (*d*, *J* = 10, H–C(15)); 9.45 (*d*, *J* = 1.5, H–C(17)). – ^{13}C-NMR.: 205.0 (*d*, C(17)); 129.2 (*s*, C(16)); 133.3 (*d*, C(15)); 50.0 (*s*, C(13)). – MS.: 448 (M^+, 33), 420 (3), 288 (20), 201 (22), 132 (100), 73 (10).

3α-Methoxy-3,19-oxido-4,4-dimethyl-16,16-trimethylenedithio-17-oxo-13α-16,17-seco-$\Delta^{5(10),14,15}$-*androstatriene* (**9**). M.p. 202.5–203°, $[\alpha]_D = -296°$ (0.69). – UV.: 254 (8500). – IR.: 2878, 2840, 2805, 2700, 1940, 1725, 1382, 1332, 908. – ^{1}H-NMR.: 1.08, 1.09, and 1.12 (3*s*, $H_3C(18)$ and 2 H_3C–C(4)); 2.84–3.06 (*m*, 2 CH_2S); 3.29 (*s*, CH_3O); 3.65 (*d*×*d*, *J* = 8, *J'* = 3) and 3.85 (*d*, *J* = 8, 2 H–C(19)); 5.59 (*d*×*d*, *J* = 4, *J'* = 2, H–C(6)); 9.29 (br. *s*, H–C(17)). – ^{13}C-NMR.: 201.8 (*d*, C(17)); 200.7 (*s*, C(15)); 111.3 (*s*, C(14)); 95.4 (*s*, C(16)). – MS.: 446 (M^+, 100), 431 (33), 418 (26), 417 (40), 371 (80), 285 (40), 119 (70), 73 (26).

3α-Methoxy-3,19-oxido-4,4-dimethyl-16-oxo-17-oxa-17aξ-acetoxy-13α-D-homo-$\Delta^{5,14}$-*androstadiene* (**10**). M.p. 228–229°. – UV.: 232 (11600). – IR.: 1745, 1720, 1625. – ^{1}H-NMR.: 1.11, 1.14, and 1.35 (3*s*, 2 H_3C–C(4) and $H_3C(18)$); 2.09 (*s*, CH_3COO); 3.31 (*s*, CH_3O); 3.88–3.92 (*m*, 2 H–C(19)); 5.63 (*d*×*d*, *J* = 5, *J'* = 2, H–C(6)); 5.93 (*d*, *J* = 2, H–C(15)); 6.21 (*s*, H–C(17a)). – MS.: 416 (M^+, 20), 356 (100).

2,2-Trimethylenedithio-3-oxo-17β-acetoxy-2,3-seco-Δ^1-*5α-androstene* (**12**). Unstable. – UV.: 213 (6500), 259 (5800). – IR.: 2856, 2722, 1735, 1720, 1600, 912. – ^{1}H-NMR.: 0.76 (*s*, $H_3C(18)$); 1.04 (*s*, $H_3C(19)$); 2.00 (*s*, CH_3COO); 2.84–3.00 (*m*, 2 CH_2S); 4.55 (*m*, H–C(17)); 5.64 (*s*, H–C(1)); 9.70 (*d*×*d*, *J* = 3, *J'* = 1.5, H–C(3)). – MS.: 436 (M^+, 4), 421 (28), 420 (94), 418 (46), 405 (17), 132 (30), 119 (11), 107 (16), 106 (5), 75 (4), 74 (2), 73 (6), 43 (100), 29 (11), 28 (3).

2-Oxo-3β,17β-diacetoxy-5α-androstane (**13**). M.p. 150.5–151°, $[\alpha]_D = +69°$ (0.54). – IR.: 1740*s*, 1720. – ^{1}H-NMR.: 0.76 (*s*, $H_3C(18)$ and $H_3C(19)$); 2.01 and 2.12 (2*s*, 2 CH_3COO); 2.47 (*d*, *J* = 11, HC(1)); 4.58 (*d*×*d*, *J* = 10, *J'* = 7, H–C(17)); 5.20 (*m*, H–C(3)). – ^{13}C-NMR.: 204.3 (*s*, C(2)); 171.1 and 169.9 (2*s*, 2 CH_3COO); 82.5 and 76.0 (2*d*, C(3) and C(17)). – MS.: 390 (M^+, 9), 375 (2), 348 (40), 330 (70), 315 (12), 288 (37), 270 (51), 255 (10), 43 (100).

3β,15β,17aξ-Triacetoxy-16,16-trimethylenedithio-17-oxa-D-homo-Δ^5-*androstene* (**14**). M.p. 160°, $[\alpha]_D = -89°$ (0.28). – UV.: *ca.* 224, 250 (750). – IR.: 1738, 1441, 1392, 911. – ^{1}H-NMR.: 1.01 and 1.23 (2*s*, $H_3C(18)$ and $H_3C(19)$); 2.02, 2.11, and 2.12 (3*s*, 3 CH_3COO); 2.80 and 3.25 (2*m*, 2 CH_2S); 4.62 (*m*, H–C(3)); 5.42 (*m*, H–C(6)); 5.47 (*d*, *J* = 3, H–C(15)); 5.83 (*s*, H–C(17a)). – ^{13}C-NMR.: 97.5 (*d*, C(17a)); 91.9 (*s*, C(16)); 70.6 (*d*, C(15)); 35.1 (*s*, C(13)). – MS.: 552 (M^+, 9), 450 (100), 119 (49), 106 (22).

6-Acetoxy-5,6-trimethylenedithio-5-hexenal (**16**). Oil (b.p. 125°/0.001 Torr). – UV.: 220*sh*, 259 (8000). – IR.: 2850*w*, 2830, 2728, 1757, 1722, 1607, 1425, 911. – ^{1}H-NMR.: 1.77 (*qi*, *J* = 7, 2 H–C(2')); 1.96–2.24 (*m*, 2 H); 2.14 (*s*, CH_3COO)); 2.34–2.68 (*m*, 4 H); 2.72–2.96 (*m*, 2 CH_2S); 9.75 (*t*, *J* = 1.5, H–C(1)). – MS.: 260 (M^+, 28), 218 (100), 190 (5), 161 (95), 145 (14), 119 (62), 106 (8), 87 (12), 75 (12), 73 (8).

6-Oxo-5,6-trimethylenedithio-hexanal (**17**). M.p. 62.5–63°. – UV.: 219 (endabsorpt.), 240 (3600), 280*sh*, 318 (130). – IR.: 2870, 2833, 2738, 1720, 1664, 1425, 1412, 908. – ^{1}H-NMR.: 1.40–2.30 (*m*, 5 H); 2.32–3.42 (*m*, 7 H); 3.67 ('*t*', *J* = 7, H–C(5)); 9.73 (*t*, *J* = 1.5, H–C(1)). – ^{13}C-NMR.: 202.0 (*d*, C(1)); 201.7 (*s*, C(6)); 52.7 (*d*, C(5)). – MS.: 218 (M^+, 41), 190 (31), 149 (22), 145 (8), 119 (71), 106 (100), 84 (17), 75 (7), 74 (22), 73 (16), 71 (10), 45 (30).

7-Oxo-6,7-trimethylenedithio-heptanal (**19**). Oil (b.p. 145°/0.007 Torr). – UV.: 220 (endabsorpt.), 239 (3600), 283*sh* (970), 318*sh* (200). – IR.: 2863, 2838, 2730, 1728, 1668. – ^{1}H-NMR.: 1.20–3.52 (*m*, 14 H); 3.66 ('*t*', *J* = 7, H–C(6)); 9.75 (*t*, *J* = 1, H–C(1)). – ^{13}C-NMR.: 202.2 (*d*, C(1)); 201.6 (*s*, C(7)); 52.7 (*d*, C(6)). – MS.: 232 (M^+, 21), 204 (25), 119 (100), 106 (93), 74 (40), 73 (33).

8,8-Trimethylenedithio-7-octenal (**21**). Oil. – UV.: 220 (endabsorpt.), 257 (6900). – IR.: 2860, 2825, 2723, 1720, 1580, 915. – ^{1}H-NMR.: 2.41 (*t*×*d*, *J* = 7, *J'* = 2, 2 H–C(2)); 1.10–3.50 (*m*, 16H); 5.91 (*t*, *J* = 7.5, H–C(7)); 9.74 (*t*, *J* = 2, H–C(1)). – MS.: 230 (M^+, 4), 202 (21), 147 (20), 146 (12), 145 (100), 119 (21), 91 (11), 75 (3), 74 (2), 73 (4), 71 (33).

8-Acetoxy-7,8-trimethylenedithio-octanal (**22**). B.p. 125°/0.015 Torr. – UV.: 220 (endabsorpt.), 257 (7500). – IR.: 2860, 2838, 2730, 1755, 1722, 1605, 1425, 911. – ^{1}H-NMR.: 1.10–1.86 (*m*, 8 H); 2.14 (*s*, CH_3COO); 1.94–2.64 (*m*, 6 H); 2.66–2.96 (*m*, 2 CH_2S); 9.74 (*t*, *J* = 2, H–C(1)). – MS.: 288 (M^+, 5), 246 (100), 218 (5), 199 (18), 161 (67), 119 (60), 106 (3), 75 (4), 74 (1), 73 (4).

8-Oxo-7,8-trimethylenedithio-octanal (**23**). Oil (b.p. 150°/0.05 Torr). – UV.: 220 (2200), 240 (3700), 285 (900), 320 (80). – IR.: 2860, 2835, 2728, 1720, 1664, 1425, 909, 867. – ^{1}H-NMR.: 1.10–2.76 (*m*, 12 H); 2.76–3.42 (*m*, 2 CH_2S); 3.66 ('*t*', *J* = 7, H–C(7)); 9.73 (*t*, *J* = 2, H–C (1)). – ^{13}C-NMR.: 202.6 (*d*, C(1)); 201.6 (*s*, C(8)); 52.8 (C(7)). – MS.: 246 (M^+, 14), 218 (22), 119 (100), 112 (11), 106 (88), 74 (15), 73 (12), 45 (15), 29 (10), 28 (6).

4-(1',3'-Dithian-2'-yliden)-cyclohexan-1-carbaldehyd (**25**). M.p. 48.5–49°. – UV.: 222 (endabsorpt.), 259 (10900), 310 (300). – IR.: 2858, 2818, 2710, 1720, 912. – ^{1}H-NMR.: 2.65–3.12 (*m*, 6 H, 2 CH_2S and ?); 9.62 (*d*, *J* = 1, CHO). – ^{13}C-NMR.: 203.8 (*d*, CO); 141.3 (*s*, C(4)); 118.2 (*s*, C(2')). – MS.: 228 (M^+, 41), 200 (31), 171 (100), 153 (70), 73 (10).

5,5-Trimethylenedithio-4-pentenal (**27**). Oil (b.p. 130°/0.08 Torr). – UV.: 217 (endabsorpt.), 256 (5070). – IR.: 2845, 2835, 2730, 1722, 1585, 913. – ^{1}H-NMR.: 2.12 (*m*, 2 H–C(2')); 2.50 (*m*, 2 H–C(2) and 2 H–C(3)); 2.82 (*m*, 2 CH_2S); 5.85 (*m*, H–C(4)); 9.71 (*t*, *J* = 0.5, H–C(1)). – MS.: 188 (M^+, 6), 160 (8), 119 (100), 113 (10), 106 (15), 75 (14), 74 (8), 73 (13), 71 (28).

5-Acetoxy-4,5-trimethylenedithio-4-pentenal (**28**). Oil (b.p. 120°/0.03 Torr). – UV.: 212 (endabsorpt.), 257 (6800). – IR.: 2838, 2828, 2728, 1755, 1725, 1605, 911, 903. – ^{1}H-NMR.: 2.14 (*s*, CH_3COO); 1.76–2.24 (*m*, 3 H); 2.40–2.96 (*m*, 7 H); 9.74 (*t*, *J* = 1, H–C(1)). – MS.: 246 (M^+, 17), 215 (8), 204 (41), 119 (41), 106 (11), 85 (64), 75 (10), 73 (8), 43 (100).

5-Oxo-4,5-trimethylenedithio-pentanal (**29**). Oil (b.p. 105°/0.02 Torr). – UV.: 220 (endabsorpt.), 239 (5000), 287 (2000). – IR.: 2860, 2838, 2738, 1724, 1664, 1425, 908. – ^{1}H-NMR.: 1.64–2.36 (*m*, 3 H); 2.36–3.38 (*m*, 7 H); 3.84 (*d* × *d*, *J* = 8, *J'* = 7, H–C(4)); 9.76 (*t*, *J* = 1.5, H–C(1)). – MS.: 204 (M^+, 53), 134 (10), 133 (10), 132 (100), 119 (30), 106 (62), 75 (5), 74 (15), 73 (11).

2-Benzylidene-1,3-dithiane (**31**) [7]. Oil (b.p. 145°/0.05 Torr). – UV.: 232 (8100), 307 (14000). – IR.: 2858, 1600, 1580, 1557, 915. – ^{1}H-NMR.: 1.96–2.30 (*m*, 2 H–C(5)); 2.70–3.06 (*m*, 2 CH_2S); 6.78 (*s*, H–C(1')); 7.0–7.5 (*m*, 5 H). – ^{13}C-NMR.: C(1') and C(2) are superimposed by C(arom). – MS.: 208 (M^+, 100), 134 (98), 90 (33), 89 (33), 77 (6).

2-Acetoxy-3-phenyl-6,7-dihydro-5H-dithiepin (**32**). Oil (b.p. 145°/0.05 Torr). – UV.: 226 (11700), 296 (14100). – IR.: 2857, 1764, 1597, 911. – ^{1}H-NMR.: 1.96–2.24 (*m*, 2 H–C(6)); 2.16 (*s*, CH_3COO); 2.84 ('*t*', *J ca.* 6.5), and 2.95 ('*t*', *J ca.* 7, 2 CH_2S); 7.16–7.52 (*m*, arom. H). – ^{13}C-NMR.: 168.3 (*s*, CH_3COO); 142.8 (*s*, C(2)); 121.6 (*s*, C(3)); 29.5 and 28.6 (2*t*, 2 CH_2S); 24.2 (*t*, C(6)); 20.6 (*q*, CH_3COO). – MS.: 266 (M^+, 44), 224 (100), 150 (28), 105 (60), 77 (32).

3-Phenyl-1,4-dithiepan-2-one (**33**). M.p. 97–98°. – UV.: 214 (endabsorpt.), 247 (15400), 270*sh* (10600), 330 (780). – IR.: 1680, 1595, 1580, 1450, 1425, 1270, 995, 915. – ^{1}H-NMR.: 1.90–2.30 (*m*, 2 H–C(6)); 2.50–2.84 (*m*, 2 H), and 3.16–3.54 (*m*, 2 H, 2 CH_2S); 5.12 (*s*, H–C(3)); 7.26–7.66 (*m*, 3 H) and 7.80–7.94 (*m*, 2 H, arom. H). – ^{13}C-NMR.: 192.5 (*s*, C(2)); 134.6 (*s*, C(1')); 133.3 (*d*, C(4')); 128.6 (4*d*, C(2') and C(3')); 42.8 (*d*, C(3)); 26.5 (2*t*); 25.1 (*t*). – MS.: 224 (M^+, 7), 149 (3), 119 (100), 106 (2), 105 (14), 91 (4), 77 (21), 75 (6), 74 (1), 73 (2), 47 (2), 28 (15).

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