Acknowledgment. The investigation was supported by grants from the National Cancer Institute (CA-12059) and the American Cancer Society (CI-102K). We thank the National Science Foundation for a grant which assisted in the purchase of a FT NMR spectrometer.

Registry No.—**3a**·HCl, 23843-20-1; **3b,** 67393-34-4; **3e,** 5977-85-5; **3g,** 60888-73-5; **3l,** 67393-35-5; **3m,** 67393-36-6; **4d,** 28230-74-2; **5c,** 22169-18-2; **7c,** 59168-20-6; **7d,** 61659-95-8; **7h,** 61659-96-9; **7i,** 16845-28-6; **15,** 56114-14-8; 1-(3,4-dimethoxybenzyl)-7-benzyloxy-6-methoxy-3,4-dihydroisoquinoline, 41183-10-2; 1-(3,4-dimethoxyphenethyl)-7-benzyloxy-6-methoxy-*N*-trifluoroacetyl-1,2,3,4-tetrahydroisoquinoline, 61660-08-0; 1-(3,4,5-trimethoxyphenethyl)-7-benzyloxy-6-methoxy-3,4-dihydroisoquinoline, 67393-37-7; 1-(3,4-dimethoxyphenethyl)-6-benzyloxy-7-methoxy-*N*-trifluoroacetyl-1,2,3,4-tetrahydroisoquinoline, 61660-07-9; piperonal, 120-57-0; tyramine, 51-67-2.

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1,4-Diketones from Skipped Acetylenes

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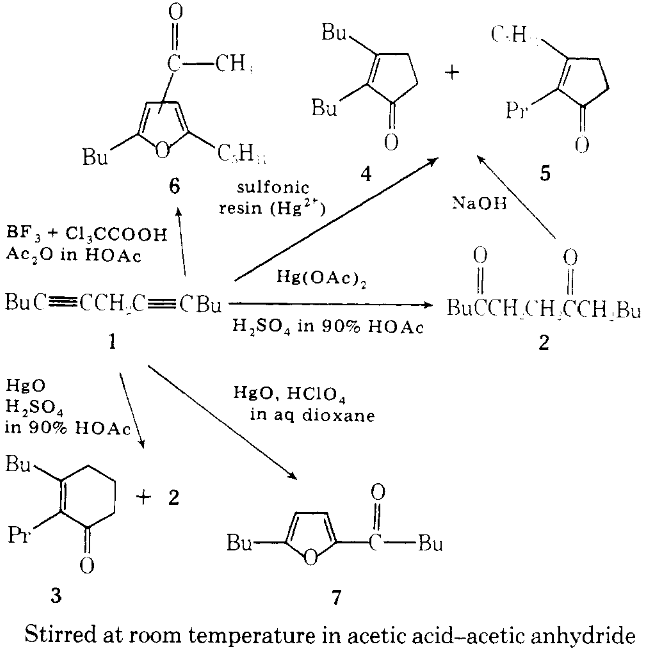
Under various acidic hydrating conditions, 5,8-tridecadiyne gives rise to 5,8-tridecanedione, 2-propyl-3-butyl-2-cyclohexenone, 2-propyl-3-pentyl-2-cyclopentenone, 2,3-dibutyl-2-cyclopentenone, 2-pentanoyl-5-butylfuran, and acetylated 2-butyl-5-pentylfuran. 1,4-Nonadiyne yields 2,5-nonanedione and also can give 5-butylfurfural; 1,4,7-dodecatriyne yields 2,5,8-dodecanetrione. Reaction pathways are proposed that rely on neighboring group effects to direct the course of the several processes.

1,4-Dicarbonyl compounds[1-5] are recognized as useful precursors for preparing five-membered heterocycles as well as cyclopentenones. We wish to report a new general synthesis of this kind of carbonyl compound by the hydration of 1,4- (or skipped) acetylenes, which can be obtained readily by coupling acetylenic Grignard reagents with propargyl bromides. This paper describes the results with 5,8-tridecadiyne (1)[6] and 1,4-nonadiyne (8),[7] which furnish, respectively, 5,8-tridecanedione (2) and 2,4-nonanedione (9), as well as other products. Skipped triyne, 1,4,7-dodecatriyne (12),[7] also has been investigated, and shown to give 2,5,8-dodecanetrione (13).

Results

Hydration[8] of 5,8-tridecadiyne (1) in aqueous acetic acid in the presence of mercuric acetate and sulfuric acid produced 5,8-tridecanedione (2) in 70% yield. Substitution of mercuric oxide for the mercuric acetate gave the same diketone, although now it was accompanied by small amounts of 2-propyl-3-butyl-2-cyclohexenone (3). When a sulfonated resin loaded with mercuric ion[9] was used as a solid catalyst, none of the diketone 2 was obtained; instead the product was a mixture of cyclopentenones 4 and 5 together with a little cyclohexenone 3. The same cyclopentenones 4 and 5 free of cyclohexenone were obtained more conveniently by cyclizing 5,8-tridecanedione (2) with base.[10]

Scheme I



Stirred at room temperature in acetic acid–acetic anhydride containing trichloroacetic acid, mercuric oxide, and boron

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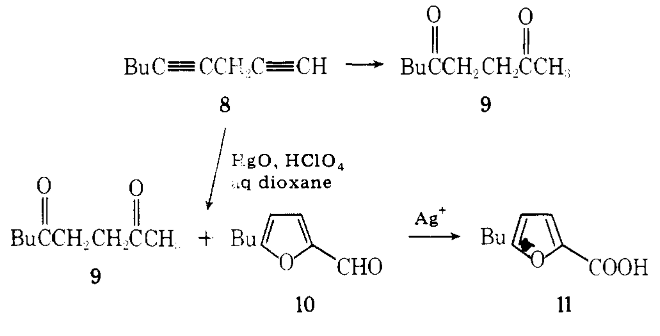
trifluoride,[11] diyne 1 cyclized to an acetylated furan, to which we have assigned the structure of ring acetyl-2-butyl-5-pentylfuran (6). Finally, with aqueous dioxane in the presence of perchloric acid and mercuric ion,[12] an oxidative process occurred giving 2-pentanoyl-5-butylfuran (7) in 65% yield.



Trials with terminally unsaturated skipped acetylenes showed that these compounds also lead to 1,4-diketones. Thus, 1,4-nonadiyne (8) with the mercuric acetate catalyst gave 2,5-nonanedione (9)[3] in 67% yield. Application of the mercuric oxide–perchloric acid conditions led to the same 2,5-nonadione (9) now accompanied by 5-butylfurfural (10). The nature of the aldehyde product was established by relating it to 5-butylfuroic acid (11), which was obtained from methyl furoate. The triply unsaturated compound, 1,4,7-dodecatriyne (12), afforded 2,5,8-dodecanetrione (13) in good yield. On the reasonable assumption that no carbonyl group can develop past the dodecane 8 position, formulation 13 is fully consistent with the spectroscopic properties of the product.

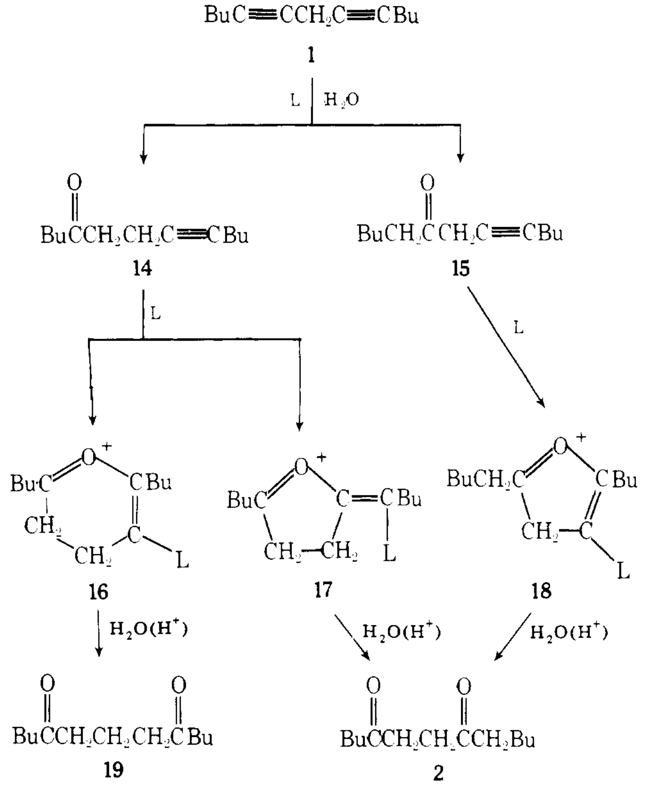
$$\underset{12}{BuC{\equiv}CCH_2C{\equiv}CCH_2C{\equiv}CH} \rightarrow \underset{13}{BuCOCH_2CH_2COCH_2CH_2COCH_3}$$

Reaction Sequence. Hydration of skipped acetylene can lead, a priori, to more than one ketonic product. For example, diyne 1 could give the diketones 6,8-nonanedione, 5,8-nonanedione (2), or 5,9-nonanedione. Significantly, none of the 1,3- or the 1,5-diketones were observed, the only diketonic product detected being the 1,4-diketone 2. Interpretations based on internally directed processes account for this selectively.

Thus starting with 5,8-tridecadiyne (5), the yne–ones 14 and 15 are taken to form in an unexceptional way. In the second stage of the hydration, possible intermediates would include the five-membered heterocycles 17 and 18 and (or) the six-membered heterocycle 16. Hydrolysis of 17 or 18 would give the observed 1,4-diketone 2, whereas 16 would give the 1,5-diketone 19. The preferred formation of the 1,4-diketone can be understood if five-membered rings as in 17 and 18 form and react faster than the six-membered ring, as in 16, and for that matter faster than *any* cyclic or acyclic intermediate that could lead to the 1,5- (or the 1,3) diketone. Since no intermediate yne–ones were detected at any stage in any of the reactions, the second part of the process starting from 14 and 15 must be appreciably faster than the first. The enhanced rates may be attributed to anchimeric assistance. In its outlines, this argument is analogous to that advanced before[4] to account for the preferred appearance of 1,4-diones in the hydration of γ,δ-unsaturated acetylenic ketones related to 14.

The terminally unsaturated skipped acetylenes 8 and 12 also gave 1,4-spaced carbonyls. Since there is a recognized kinetic preference for hydration of terminal acetylenes over internal acetylenes,[13] we may accept the initial formation of 2-keto-4-nonyne and 2-keto-4,7-dodecatriyne from 1,4-nonadiyne (8) and 1,4,7-dodecatriyne (12), respectively. Once these intermediates are involved, the same kind of reasoning as before, involving neighboring group effects, predicts that only carbonyls spaced at intervals of four carbon atoms will emerge.

Scheme II

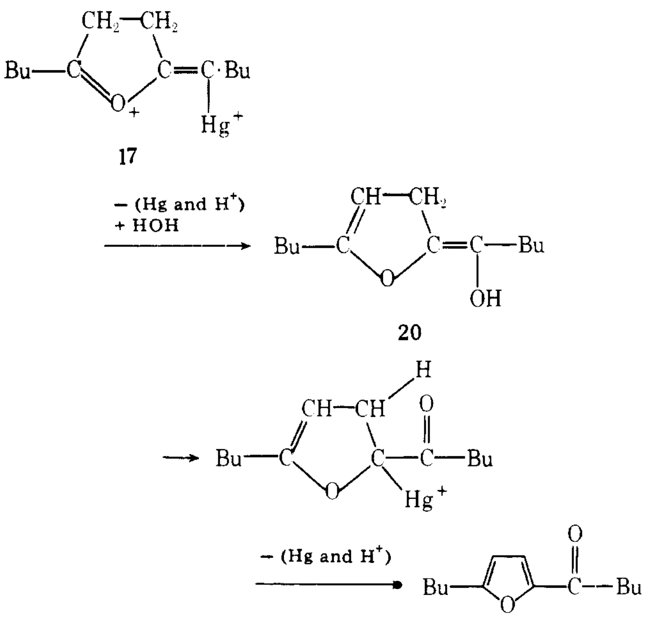


L = electrophile catalyst

Turning to the cyclic products, and considering first the cyclopentenones 4 and 5, we have no basis for not accepting formation, and then, under the same conditions, cyclization, of 5,8-tridecanedione (2). In the resin-catalyzed process, cyclopentenones 4 and 5 are obtained with 5,8-tridecadiyne or with 5,8-tridecanedione as starting material. Also relevant is the observation that the mercuric ion–sulfuric acid procedure, which after a 5-h reflux period forms 5,8-tridecanedione from 5,8-tridecadiyne, after a 3-day reflux period gives the cyclopentenone mixture 4 plus 5.[17]

In contrast, similar experimental tests show that the 1,4-diketones 2 or 9 cannot serve as intermediates in the oxidative formation of acylfurans 7 and 10. Under conditions that give furans 7 and 10, replacing the diyne starting materials 1 and 8 with diketones 2 and 9 leaves the diketones unchanged. The possibility that 2-butyl-5-pentylfuran and 2-butyl-5-methylfuran are intermediates may also be rejected. If this kind of molecule were oxidized, it is likely that the 2-pentanoyl-5-butylfuran (7), for example, would emerge as a 50:50 mixture with 2-butanoyl-5-pentylfuran. Yet no sign of twin peaks appeared in any of our routine gas-liquid chromatographic analyses. In one run, analysis with a high-efficiency (75 000–150 000 plate) capillary gas-liquid chromatographic column still showed only a single, sharp, symmetrical peak. Finally, the mass fragmentation pattern, in being consistent with 2-pentanoyl-5-butylfuran (7) but not with 2-butanoyl-5-pentylfuran, confirmed both the homogeneity and the assigned structure.

Rationalization of this oxidation process makes use of intermediate 17 as the starting point. In the pathway leading to diketone 2, the mercury group in 17 leaves as mercuric ion and is replaced with hydrogen; in the oxidative process, however, mercury leaves with its pair of electrons as metallic mercury,[15] and is replaced with hydroxyl (as in 20). A second



mercuration again followed by loss of mercury gives rise to the observed product **7**. Although other sequences can be written, this one is short, direct, and reasonable. Why oxidation occurs here but not in the other mercury-catalyzed hydrations may be related to the relatively large amounts of mercuric ion as well as to the enhanced solvolytic properties of 25% aqueous dioxane over the other solvents. A similar mechanism can be formulated for formation of 5-butylfurfural (**10**) from 1,4-nonadiyne (**8**).

To reach cyclohexenone **3**, we assume as intermediate the 1,5-dicarbonyl compound **19** which undergoes acid catalyzed aldol cyclization to give **3**.[16,17] The fact that the cyclohexenone **3** was invariably obtained in poor yield as a minor product agrees with the postulated slow rate of formation of intermediate **16**.

The boron trifluoride process converting 5,8-tridecadiyne (**1**) to acetylated furan **6** is run under anhydrous conditions. Here, a straightforward reaction pathway calls for cyclization to 2-butyl-5-pentylfuran, which then undergoes ring acetylation.[18] Whether 5,8-tridecanedione (**2**) would give the acetylated furan **6** under the conditions used was not investigated.

Summary. Skippd diynes and triynes have been shown to be useful and convenient precursors in the preparation of polyketones and various hetero- and homocyclic derivatives. Under appropriate conditions, the following compounds were prepared in practical though still not optimized yield: from 5,8-tridecadiyne (**1**), 5,8-tridecanedione (**2**, 71%), 2,3-dialkylcyclopentenones (**4** and **5**, 62%), acetylated 2-butyl-5-pentylfuran (**6**, 55%), and 2-pentanoyl-5-butylfuran (**7**, 65%); from 1,4-nonadiyne (**8**), 2,5-nonanedione (**9**, 67%); and from 1,4,7-dodecatriyne (**12**), 2,5,8-dodecanetrione (**13**, 63%). Other compounds were also obtained in lower yield. Reaction sequences accounting for these products have been proposed.

Experimental Section

General. Analyses for elements' content were obtained from Galbraith Laboratories, Inc., Knoxville, Tenn., Scandinavian Microanalytical laboratory, Herlev, Denmark, and Carol K. Fitz, Carlisle, Mass. Temperatures are uncorrected. Melting points were taken in open capillary tubes.

5,8-Tridecanedione (2) from 5,8-Tridecadiyne (1). After allene-free 5,8-tridecadiyne (**1**) (4.4 g or 25 mmol) was added to mercuric acetate (0.6 g, 2 mmol) in 30 mL of 90% acetic acid–10% water plus 0.25 mL (4 mmol) of concentrated sulfuric acid, the solution under nitrogen was stirred and refluxed for 5 h.[19] Turbidity developed gradually, and occasionally mercury was deposited. Sodium hydroxide (18 g) in water (100 mL) was added (cooling), and product was extracted with several portions of carbon tetrachloride. The combined extracts, after rinsing with water, were dried and stripped of volatiles. Two crystallizations of the residue (5.0 g) from aqueous ethanol furnished 3.7 g (71%) of white crystalline plates of 5,8-tridecanedione (**2**): mp 40.5–41.5 °C; bp 123–125 °C (0.4 mm); IR (CCl_4 or isooctane) 1715 cm^{-1}; UV (6×10^{-3} M) in methanol, λ_{max} 274 nm (log ϵ 1.72) and in cyclohexane, 268.5 nm (1.72);[20] NMR (CCl_4) δ 2.55 (s, 6,7-di-CH_2), 2.38 (t, J = 6.5 Hz, 4,9-di-CH_2), 1.35 (m, five CH_2's), and 0.90 (t, J = 5.5 Hz, 2 CH_3). The integration ratio above and below δ 2 was 8:16 as required.

Anal. Calcd for $C_{13}H_{24}O_2$: C, 73.54; H, 11.39. Found: C, 73.7; H, 11.4.

When a reaction mixture consisting of 5,8-tridecadiyne (8.1 mmol), 95% alcohol (15 mL), water (4 mL), mercuric sulfate (0.6 g), and concentrated sulfuric acid (0.05 mL)[21] was refluxed for 24 h, the major product was again 5,8-tridecanedione (55%); trace amounts of cyclohexenone **3** and furan **7** were also formed under these conditions.

To confirm the assigned structure of 5,8-tridecadione (**2**) it was converted to a pyrrole derivative by heating with *p*-bromaniline in the presence of a trace of hydrochloric acid. 1-(*p*-Bromophenyl)-2-butyl-5-pentylpyrrole, bp 130–145 °C (0.05 mm), was obtained in 68% yield.

Anal. Calcd for $C_{19}H_{26}BrN$: C, 65.51; H, 7.52; Br, 22.94; N, 4.02. Found: C, 65.67; H, 7.50; Br, 22.65; N, 4.03.

The IR and NMR absorption spectra for this pyrrole were entirely consistent with the spectra determined for 1-(*p*-bromophenyl)-2,5-dimethylpyrrole, mp 73–73.5 °C (lit.[22] 74 °C), prepared for comparison.

The bis(2,4-dinitrophenylhydrazone) from 5,8-tridecanedione crystallized from aqueous dioxane as an orange solid, mp 185–186 °C.

Anal. Calcd for $C_{25}H_{32}N_8O_8$: N, 19.6. Found: N, 19.3.

2-Propyl-3-butyl-2-cyclohexenone (3) from 5,8-Tridecadiyne (1). Diyne **1** (1.3 g, 7.6 mmol) in 13 mL of 90% acetic acid and 0.13 mL of concentrated sulfuric acid containing 0.2 g (0.9 mmol) of yellow mercuric oxide was refluxed in an atmosphere of nitrogen for 4 h. Ether extraction, etc., furnished 1.5 g of a brown, solvent-free product, containing 15% of 2-propyl-3-butyl-2-cyclohexenone (**3**) and 70% of 5,8-tridecanedione (**2**). Distillation through a spinning band column led to fractions richer in the cyclohexenone but still not free of diketone. Preparative gas-liquid chromatography (Chromosorb at 178 °C) afforded the desired cyclohexenone **3** (6%) as the faster moving fraction.

Homogeneous 2-propyl-3-butyl-2-cyclohexenone (**3**) was obtained as a faintly yellow oil: IR (CCl_4) 1710, 1660, 1620 cm^{-1}; UV (4.5×10^{-5} M in methanol) λ_{max} 247 nm (log ϵ 3.95) or (5.5×10^{-5} M in cyclohexane) 238 (4.08); NMR (CCl_4) δ 2.15 (m, 10, ring CH_2's plus CH_2's attached to positions 2 and 3), 1.40 (m, 6, other CH_2's), 0.95 (m, 5, CH_3's).

Anal. Calcd for $C_{13}H_{22}O$: C, 80.35; H, 11.41 Found: C, 80.12; H, 11.37.

Various other appropriate spectroscopic data are available in the literature for comparison.[4,17,23]

In a similar mixture, where 5,8-tridecanedione (**2**) was taken as reactant in place of 5,8-tridecadiyne (**1**), after a 10-h reflux period, no cyclic ketone was present; unchanged dione was the only material isolated (92% crude; 68% pure).

2-Propyl-3-pentyl-2-cyclopentenone (5) and 2,3-Dibutyl-2-cyclopentenone (4) A. From 5,8-Tridecanedione (2). A mixture of 5,8-tridecanedione (0.28 g or 1.3 mmol), 7 mL of methanol, 7 mL of water, and sodium hydroxide (1.4 g) was refluxed under nitrogen for 5 h. Standard processing afforded an oil (0.23 g), which according to gas-liquid chromatography consisted of a single material different from cyclohexenone **3**. Distillation gave 0.17 g (64%) of the desired mixture of 2-propyl-3-pentyl- and 2,3-dibutyl-2-cyclopentenone (**5** and **4**): bp 110–120 °C (0.62 mm); IR (CCl_4) 1705, 1645 cm^{-1}; UV (ethanol, 6.4×10^{-5} M) λ_{max} 237 nm (log ϵ 4.19); NMR (CCl_4) δ 2.2 (m, 8, ring CH_2's plus CH_2's attached to ring), 1.4 (m, all other CH_2's), 0.9 (m, CH_3 groups). The last two signals corresponded to 14 protons. Ultraviolet, IR, and NMR data for many similarly constituted cyclopentenones are available and are consistent with our values.[24]

Anal. Calcd for $C_{13}H_{22}O$: C, 80.35; H, 11.41. Found: C, 80.56; H, 11.38.

The action of dione **2** with 1% sodium ethoxide in absolute alcohol for 15 min led to complete recovery of unchanged dione.

B. From 5,8-Tridecadiyne (1). A solid catalyst was prepared from 10 g of a finely ground commercial sulfonated polystyrene resin (Dowex 50X-4) by first treating the powder with 2 N sulfuric acid and then stirring it overnight in a solution of 0.1 g of mercuric oxide in 200 mL of 2 N sulfuric acid. The resin was washed repeatedly with water and then stored in vacuo over calcium sulfate for 1 day.

A refluxing mixture of 5,8-tridecadiyne (**1**, 0.96 g, 5.4 mmol) in 10 mL of glacial acetic acid and 1 mL of water containing 2 g of the prepared resin was stirred for 3 days under nitrogen. Addition of water, extraction with ether, and the appropriate aqueous rinses afforded 1.11 g of a yellow solvent-free oil, which by gas-liquid chromatographic analysis contained 0.66 g (62%) of 2-propyl-3-pentyl-2-cyclopentenone (**5**) plus 2,3-dibutyl-2-cyclopentenone (**4**) as well as 0.21 g (20%) of 2-propyl-3-butyl-2-cyclohexenone (**3**).

The same products were obtained in about the same amounts when the reactant mixture (tridecadiyne **1** with Hg^{2+}, aqueous acetic acid, and H_2SO_4) used to prepare 5,8-tridecanedione (**2**) from tridecadiyne **1** was refluxed for 3 days instead of 5 h.

In the resin-catalyzed reaction, when 5,8-tridecanedione (**2**) was taken as starting material in place of 5,8-tridecadiyne (**1**), no cyclohexenone **3** was formed and no dione was recovered. The single product was the cyclopentenone mixture **4** and **5**.

2-Pentanoyl-5-butylfuran (7) from 5,8-Tridecadiyne (1). The reaction mixture contained diyne **1** (2.0 g, 0.011 mol) in a solution of yellow mercuric oxide (12 g; 0.055 mol) in 32 g of 70% perchloric acid plus 15 mL of water and enough dioxane to bring the final volume to 80 mL. After the mixture was stirred under nitrogen at room temperature for 45 min, 80 mL of water was added, and ether was used to extract product. Some metallic mercury was noted. The ether solution was washed with water, dried, and then warmed to remove all volatiles. Distillation of the residual oil gave 1.5 g (65%) of very faintly yellow 2-pentanoyl-5-butylfuran (**7**), bp 82–96 °C (0.04 mm), which according to gas-liquid chromatography was 99% pure. The product showed the following spectral properties: IR (neat) 1675, 1585, 1520 cm^{-1}; UV (2×10^{-5} M in methanol) λ_{max} 286 nm (log ϵ 4.2), 221 (3.48); NMR (CCl_4) δ 6.99 (d, J = 3.5 Hz, 1, furan H), 6.11 (d, J = 3.5 Hz, 1, furan H), 2.71 (t, J = 6.5 Hz, 4, furyl CH_2 plus CCH_2), 1.5 (m, remaining CH_2), 0.94 (distorted t, J = 6 Hz, methyl groups). Combined integration of the δ 1.5 and 0.94 signals showed 14 protons as required. In the mass spectrum, the molecular peak was observed at *m/e* 208; the base peak at 166 was assigned to the McLafferty cleavage fragment, $C_{10}H_{14}O_2{}^{+}\cdot$; intense peaks at 151 and 123 were attributed respectively to the 2-furoyl-5-butyl and the 5-butylfuryl ion radicals.[25]

Anal. Calcd for $C_{13}H_{20}O_2$: C, 74.94; H, 9.68. Found: C, 74.76; H, 9.91.

When 5,8-tridecanedione (**2**) was used in this reaction instead of 5,8-tridecadiyne (**1**), the only product was unchanged dione (82%), mp 38.5–40 °C; no infrared absorption peak appeared at 1675 cm^{-1}.

3(or 4)-Acetyl-2-butyl-5-pentylfuran (6) from 5,8-Tridecadiyne (1). 5,8-Tridecadiyne (1.0 g, 5.8 mmol) was added to a solution of yellow mercuric oxide (0.50 g, 2.3 mmol) in trichloracetic acid (0.1 g, 0.6 mmol), acetic anhydride (10 mL), acetic acid (40 mL), and freshly distilled boron trifluoride etherate (1 mL), and the reaction mixture was stirred under nitrogen for 24 h. The mixture was processed by adding water (ice cooling), extracting with ether, and appropriately washing, etc., to get 1.3 g of a yellow, viscous liquid. Quantitative gas-liquid chromatography (hexadecyl bromide internal standard) showed that this liquid contained a major component, the acetylated butylpentylfuran (**6**, 0.76 g, 55%), as well as a minor component recognized as 2-propyl-3-butyl-2-cyclohexenone (**3**, 0.14 g or 10%).

Preparative gas-liquid chromatography (Chromosorb with neopentyl glycol succinate at 186 °C) afforded homogeneous 3(or 4)-acetyl-2-butyl-5-pentylfuran (**6**): IR (CCl_4) 1675, 1600, 1560, 1510 cm^{-1}; UV (6×10^{-5} in methanol) λ_{max} 280 nm (log ϵ 3.74) and in cyclohexane solvent at 5.5×10^{-5} M, 273 (3.76); NMR (CCl_4) δ 6.10 (s, 1, furan H), 2.90 (t, J = 7 Hz, 2, CH_2 furan next to acetyl), 2.55 (t, J = 7 Hz, 2, CH_2 furan opposite to acetyl), 2.25 (s, 3, CH_3CO), 1.43 (m, other CH_2's), 0.88 (distorted t, J = 6 Hz, alkyl CH_3's). Integration of the two high-field signals together showed 16 protons. The spectral properties (IR, UV, and NMR) of 3-acetyl-2,5-dimethylfuran, prepared for comparison according to Hurd and Wilkinson,[26] were in good agreement with those of **6**. The semicarbazone of 3(or 4)-acetyl-2-butyl-5-pentylfuran (**6**) melted at 97–99 °C.

Anal. Calcd for $C_{16}H_{27}N_3O_2$: C, 65.50; H, 9.28; N, 14.32. Found: C, 65.23; H, 9.26; N, 14.06.

2,5-Nonanedione (9) from 1,4-Nonadiyne (8). A mixture of 10.0 g (83 mmol) of 1,4-nonadiyne, mercuric acetate (1.0 g, 3.1 mmol), and concentrated sulfuric acid (0.5 mL) in 100 mL of 90% acetate acid was refluxed for 2 h. The dark reaction mixture containing some mercury was poured into cold water (200 mL) and extracted with ether. The ether extracts were washed with bicarbonate and with water, dried, and distilled to give faintly yellow 2,5-nonanedione (9.2 g, 67%): bp 76–78 °C (0.2 mm); $n^{25}{}_D$ 1.4327; IR (CCl_4 or isooctane) 1725 cm^{-1}; UV (10^{-3} M in methanol) λ_{max} 274 nm (log ϵ 2.47); NMR (neat) δ 2.63 (s, 3,4-di-CH_2), 2.42 (t, J = 6.5 Hz, 2, CH_2 at 6), 2.07 (s, 3, CH_3CO), 1.4 (s, 7,8-di-CH_2), 0.88 (distorted t, J = 6 Hz, CH_3 at 9). Integration of the last two signals showed a total of 7 protons. No signals appeared at δ 9.2–10.3 even in the crude product.

Anal. Calcd for $C_9H_{16}O_2$: C, 69.19; H, 10.31. Found: C, 69.4; H, 10.3.

The product before (85% yield) and after distillation gave the same gas-liquid chromatograms.

The bis(2,4-dinitrophenylhydrazone) of 2,5-nonanedione (**9**), after crystallization from ethyl alcohol–ethyl acetate (7:4), showed mp 180.5–181.5 °C.

Anal. Calcd for $C_{21}H_{24}N_8O_8$: C, 48.83; H, 4.68; N, 21.70. Found: C, 48.9; H, 4.7; N, 21.5.

Hydration of 1,4-nonadiyne (**8**) with mercuric sulfate (0.82 g) in 87% fornic acid (8.2 mL) for 20 min at 0 °C afforded appreciable 2,5-dione as well as unchanged diyne (40%).

5-Butylfurfural (10). Hydration of 1,4-nonadiyne (**8**) with mercuric oxide (18.4 g, 0.085 mol) dissolved in 70% perchloric acid (24.6 g, 0.17 mol, or 55 g, 0.38 mol) containing water (20.4 mL) and enough dioxane to bring the total volume to 120 mL was effected by stirring the mixture under nitrogen at room temperature for 45 min. 2,5-Nonanedione (**9**) as well as a new product, taken as 5-butylfurfural (**10**), were obtained, both in low yield. An NMR absorption curve for the mixture included signals at δ 9.50 (CHO) as well as two doublets at δ 6.99 and 6.11 (aromatic furan H's), which integrated to a proton ratio of 1:1:1. When 2,5-nonanedione was used as starting material here instead of 1,4-nonadiyne, no furfural product was detected; the homogeneous dione was recovered to an extent of 94%.

5-Butylfuroic Acid (11). A. From the 5-Butylfurfuraldehyde Hydration Product. The crude mixture containing the two products from the mercuric oxide–perchloric acid reaction was suspended in a mixture of silver nitrate (6.7 g), sodium hydroxide (3.2 g), and water (70 mL) and was stirred at reflux temperature for 40 min. After neutralization with 2 *N* hydrochloric acid, the mixture was filtered and both the solids and the filtrate were extracted with ether. Acidic material was brought into concentrated bicarbonate solution and was recovered by adjusting the pH to 2, saturating the mixture with sodium chloride, and extracting with ether. 5-Butylfuroic acid (**11**), mp 66.5–69 °C, was obtained from the extracted solids after several low-temperature crystallizations from aqueous ethanol. Mixed with authentic 5-butylfuroic acid (mp 69–70 °C), this product showed mp 67–69.5 °C. Both materials gave single peaks on gas-liquid chromatography appearing at the same retention time.

B. From Methyl Furoate.[27] Stannic chloride (78 g, 0.30 mol) was dropped into a nitrogen-blanketed, ice-cold mixture of methyl furoate (13 g, 0.10 mol) and butyric anhydride (16 g, 0.10 mol) over a period of 1 h. The mixture was stirred for 3 days at room temperature and then for 1 day at 45–50 °C. Addition of ice-cold water (300 mL), followed by standard proceedings, afforded 4.3 g of methyl 5-butanoylfuroate, mp 66–67 °C, after two crystallizations from 95% alcohol (lit.[27] mp 67–68 °C).

Saponification led to the corresponding acid, 5-butanoylfuroic acid, mp 179. 5–180.5 °C (lit.[28] 176 °C), which was reduced as follows to remove the carbonyl oxygen. Hydrazine hydrate (0.6 mL, 12 mmol) was added dropwise to 5-butanoylfuroic acid (0.60 g, 3.3 mmol) in 10 mL of absolute alcohol. After a 15-min reflux, the mixture was cooled, treated with potassium *tert*-butoxide (3.0 g, 27 mmol) in 20 mL of absolute alcohol, and then over a period of 1.5 h gradually warmed to 200 °C, during which time solvent was escaping. The reaction mixture was then held at 200 °C for 25 min. The cooled alkaline system was diluted with 10 mL of cold water, acidified to pH 3 with hydrochloric acid, saturated with sodium chloride and the acid mixture extracted with ether. Recrystallization of the crude product from aqueous alcohol gave 0.38 g (68%) of 5-butylfuroic acid: mp 69–70 °C; IR (mineral oil mull) 3550, 3000, 1695 cm^{-1}; UV (10^{-4} M in 95% EtOH) λ_{max} 257 nm (log ϵ 4.03); NMR (CCl_4) δ 11.55 (broad s, 1, COOH), 7.10 (d, J = 3.5 Hz, 1, 2-furyl-H), 6.05 (d, J = 3.5 Hz, 1, 3-furyl-H), 2.65 (t, J = 7.2 Hz, CH_2 attached to furan), 1.5 (m), and 0.90 (t, 7, all other protons).

Anal. Calcd for $C_9H_{12}O_3$: C, 64.27; H, 7.19. Found: C, 64.09; H, 7.11.

2,5,8-Dodecanetrione (13) from 1,4,7-Dodecatriyne (12). A mixture of 1,4,7-dodecatriyne (2.4 g, 15 mmol) and mercuric acetate (0.7 g, 2 mmol) in 25 mL of 90% acetic acid containing 0.25 mL of concentrated sulfuric acid was stirred and refluxed under nitrogen for 2.5 h. The cooled mixture was made basic with aqueous sodium hydroxide before extraction with carbon tetrachloride. The extract was rinsed, dried, and distilled to give 2.0 g (63%) of faintly yellow trione **13**, bp 106.5–108 °C (0.57 mm), which solidified in the receiver. After charcoal decolorization (ether solution), the product was recrystallized from aqueous ethanol. The white, crystalline, 2,5,8-dodecanetrione (**13**, 38%) had mp 57.5–58 °C: IR (CCl_4) 1715 cm^{-1}; UV (10^{-2} M in methanol) λ_{max} 217 nm (log ϵ 1.91); NMR (CCl_4) δ 2.61 (s, 8, CH_2's at positions 3, 4, 6, 7), 2.35 (t, $J = 6.5$ Hz, 2, CH_2 at position 9), 2.11 (s, 3, $COCH_3$), 1.55 and 0.90 (7, remaining H's).

Anal. Calcd for $C_{12}H_{20}O_3$: C, 67.89; H, 9.50. Found: C, 68.00; H, 9.43.

No infrared absorption maximum appeared at 1625 cm^{-1} (α,γ-dione), and no NMR signal appeared in the δ 10 region (aldehyde H).

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Registry No.—**1**, 67238-15-7; **2**, 67238-16-8; **2** bis(2,4-DNP), 67238-17-9; **3**, 67238-18-0; **4**, 67238-19-1; **5**, 67238-20-4; **6**, 67238-52-2; **6** semicarbazone, 67238-53-3; **7**, 67238-21-5; **8**, 6088-94-4; **9**, 25234-82-6; **9** bis(2,4-DNP), 67238-22-6; **10**, 23074-13-7; **11**, 67238-23-7; **12**, 67238-24-8; **13**, 67238-25-9; 1-(*p*-bromophenyl)-2-butyl-5-pentylpyrrole, 67238-26-0; methyl 5-butanoylfuroate, 67238-27-1; 5-butanoylfuroic acid, 67238-28-2; *p*-bromoaniline, 106-40-1; butyric anhydride, 106-31-0.

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