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1,3,5-Trineopentylbenzene

I. Synthesis and Reduction of 1,3,5-Tripivaloylbenzene

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1,3,5-Tripivaloylbenzene has been prepared by trimerization of pivaloylacetaldehyde in two ways, by a cyclic modification of the Knoevenagel reaction as well as by refluxing in acetic acid. 1,3,5-Trineopentylbenzene has been prepared by reduction *via* 1,3,5-tripivaloylbenzene trihydrazone as well as *via* the trisethylenethioketal. From 1,3,5-tripivaloylbenzene there has also been prepared 1,3,5-tris(2,2-dimethylpropane-1-ol)benzene by reduction and 1,3,5-tris-(1,2,2-trimethylpropane-1-ol)benzene by means of methyl magnesium iodide. NMR and IR data are reported for all these novel compounds, and mass spectra for three of them. NMR studies reveal a hindered rotation around the $C_{sp^3}-C_{sp^3}$ bonds in 1,3,5-tris(1,2,2-trimethylpropane-1-ol)benzene. The barrier is estimated to be greater than 25 kcal/mole.

The synthesis of 1,3,5-trineopentylbenzene was started with the intention to make a new, highly branched alkylbenzene available for physical organic investigation. One of the main objectives is to study the electrophilic substitution reactions of this compound with the isotope effect technique, and compare the results with those obtained for other symmetrical trialkylbenzenes, *e.g.* mesitylene,[1] 1,3,5-triethylbenzene,[2] and 1,3,5-tri-*t*-butylbenzene.[3] This work is now going on in this laboratory and will be reported later. There is also a general renewed interest in the behaviour of compounds containing neopentyl groups [4,5] which prompted the preparation of the present, unreported hydrocarbon.

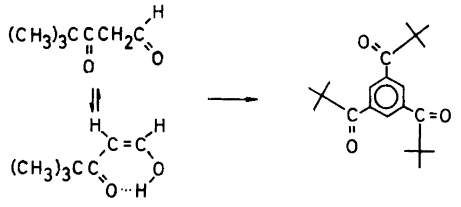
Of the possible synthetic routes, Friedel-Crafts alkylation was considered less satisfactory because of the sensitivity of the neopentyl cation to rearrangement. There are, however, two other methods that have both led to the goal. One involves the cyclic trimerization of methyl neopentyl ketone, which has been investigated and will be the subject of the next paper in this series.* The present paper deals with the other successful method, synthesis and reduction of 1,3,5-tripivaloylbenzene.

* *Added in proof:* Part II: *Acta Chem. Scand.* **22** (1968) 2382.

SYNTHESES

1,3,5-Tripivaloylbenzene (II) could not be found in the literature, but a possible synthetic method was indicated by the reports that formylacetone [6] and benzoylacetaldehyde [7] easily trimerize to the corresponding 1,3,5-triacylbenzenes, spontaneously and by heating in acetic acid, respectively. The required monomer pivaloylacetaldehyde (I) has been prepared by several workers from pinacolone and ethyl formate by means of sodium,[8] sodium ethoxide,[9] or sodium amide.[10] It was found advantageous, however, to apply the sodium hydride method reported by Ainsworth *et al.* for the preparation of β-ketoaldehydes.[11] In this way pivaloylacetaldehyde (hydroxymethylenepinacolone) was obtained in 66 % yield. The name in parenthesis is supported by the fact that the compound was shown by NMR to be enolized to an extent of about 94 %.

During the vacuum distillation of the aldehyde the formation of a crystalline substance, later identified as 1,3,5-tripivaloylbenzene (II), was noticed. A check of this uncatalysed thermal trimerization showed it not to be promising, but by refluxing the β-ketoaldehyde in acetic acid a 30 % yield of (II) was obtained. Pivaloylacetaldehyde could also be expected to self-trimerize under Knoevenagel conditions behaving as an aldehyde as well as an active methylene compound.* This was actually found to work. Using ordinary conditions [12] with toluene as a solvent, piperidinium acetate as the catalyst, and a water separator afforded 1,3,5-tripivaloylbenzene in 40 % yield.



(I) (II)

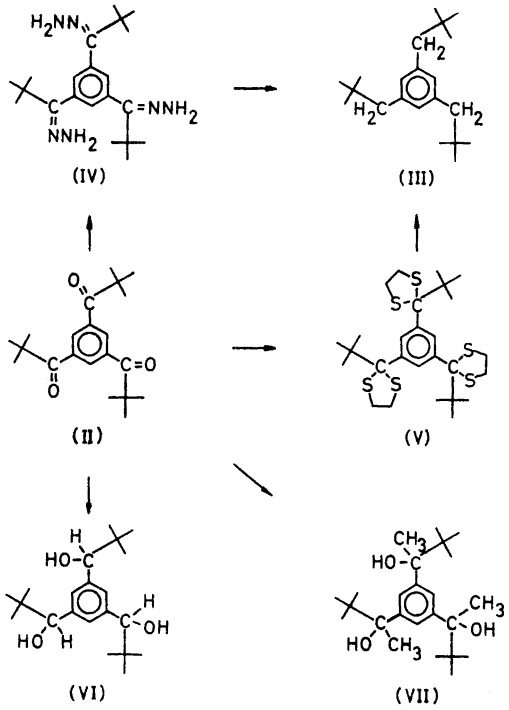
1,3,5-Trineopentylbenzene (III). Different reduction methods have been tested upon 1,3,5-tripivaloylbenzene. Clemmensen reduction afforded a complex mixture of products. One of the peaks in the gas chromatogram of the product mixture had the same retention time as a sample of authentic 1,3,5-trineopentylbenzene (III) made as described below. The mixture was not further analysed and the isolation of (III) was considered unfavourable.

An attempt to carry out a Huang-Minlon-Wolff-Kishner reduction of (II) also afforded a complex product mixture with minor amounts of (III), but treatment of the pre-isolated 1,3,5-tripivaloylbenzene trihydrazone (IV) with potassium hydroxide in triethyleneglycol at 190°C during 5 h yielded 75 % of (III). The finding that a sterically hindered carbonyl group is dif-

* Suggested by Dr. Arne Brändström.

ficult to reduce by the normal, non-anhydrous Wolff-Kishner procedure may have some bearing upon the work reported by Barton *et al.* on the reduction of sterically hindered carbonyl groups in some natural products.[13]

When (II) was treated with 1,2-ethanedithiol and boron trifluoride etherate, white crystals soon appeared. According to NMR and IR they were assumed to be the 1,3,5-tripivaloylbenzene trisethylenethioketal (V). Hydrogenolysis of (V) with Raney nickel in ethanol yielded (III) in 90 % yield.

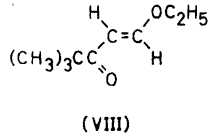


Catalytic reduction of (II) in neutral as well as acidic media was found to give the corresponding triol, *1,3,5-tris(2,2-dimethylpropane-1-ol)benzene (VI)* and no hydrocarbon. This correlates well with the findings reported[14] that complete substitution in the α-position of an aryl alkyl ketone inhibits hydrogenolysis of the corresponding benzyl alcohol formed on reduction.

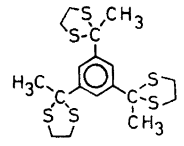
Compound (II) was also subjected to a reaction with a Grignard reagent, methyl magnesium iodide. The conditions chosen were similar to those reported by Wibaut and Paulis in their investigation[15] of the step-wise reaction of 1,3,5-triacetylbenzene with this Grignard reagent. They isolated a mixture of products, consisting of all possible keto-carbinols, with at best 19 % of the fully reacted product, 1,3,5-tris(1-methylethane-1-ol)benzene. In the present case it was possible to drive the reaction very far to the triol stage with isolation of only one product, *1,3,5-tris(1,2,2-trimethylpropane-1-ol)benzene (VII)*, in 75 % crude yield.

IDENTIFICATION AND DISCUSSION OF SPECTRA

Hydroxymethylenepinacolone (I) and *ethoxymethylenepinacolone (VIII)* were obtained as described in the experimental section. The NMR spectra of these compounds, measured without solvent, have many similarities. Both have the *t*-butyl peak at 1.16 ppm * and both reveal an ethylenic AB-system centered at 6.85 ppm. The chemical shifts and the coupling constants, however, are different in the two compounds. The values of (I), $\delta_A=5.72$ and $\delta_B=7.98$ ppm, $J_{AB}=5$ Hz, are consistent with the enol form of (I) being present in the hydrogen bonded *sym-cis* form, with the aldehydic carbonyl enolized rather than the ketonic one.[16] A broad signal at 14.33 ppm is assigned to the OH protons. In the spectrum of (I) the absorption of the methylene protons as well as the aldehydic ones of the keto form was also observable at 3.58 and 9.77 ppm, respectively. According to the integrals they corresponded to about 6 % keto form. The values of (VIII), $\delta_A=6.05$ and $\delta_B=7.65$ ppm, $J_{AB}=12$ Hz, are in accord with the values expected for a *trans* substituted ethylene with the substituents acyl and alkoxy.[16]



(VIII)



(IX)

1,3,5-Tripivaloylbenzene (II). The elemental analysis of (II) indicated an empirical formula $C_{21}H_{30}O_3$, and the mass number 330 required for this formula was confirmed by the mass spectrum. The parent peak was of low intensity. The splitting off of a *t*-butyl group resulting in a peak at *m/e* 273 (M−57) evidently gives a very stable ion, because besides this and the *t*-butyl ion at *m/e* 57 there are no peaks with relative abundance greater than 14 % (besides the isotopic contribution to the parent peak). Other spectral characteristics of (II), in some respects compared to those of 1,3,5-triacetylbenzene, confirmed the suggested structure. The carbonyl stretching band in the infrared spectrum of (II) was found at 1678 cm^{-1}. In the aromatic 1600 cm^{-1} region there is a band at 1590 cm^{-1}, and the out-of-plane ring bending seems to appear at 740 cm^{-1}. The four characteristic *t*-butyl bands appeared at 1397, 1370, 1266, and 1202 cm^{-1}. These values are in good accordance with the carbonyl absorption 1692 cm^{-1}, as well as the 1589 cm^{-1} and the 690 cm^{-1} absorption in triacetylbenzene. The ultraviolet spectra can be seen to be well correlated also. The figures are summarized in the experimental section. The NMR spectrum of (II) is as simple as was expected. It reveals two peaks with areas in the ratio 27:3 at 1.39 and 8.16 ppm in CCl_4 for the *t*-butyl and aromatic protons, respectively.

* from TMS, internal standard.

Hydrazone formation shifted the NMR peaks upfield from the triketone as expected. The *t*-butyl groups and the aromatic protons of (*IV*) were found at 1.15 and 6.88 ppm, respectively, whereas the broad amino peak was centered at about 4.73 ppm. In the IR spectrum only three of the expected *t*-butyl bands could be found at 1391, 1360, and 1202 cm^{-1}. The rather intense band at 1266 cm^{-1} in the ketone spectrum has no counterpart in the hydrazone spectrum, except possibly the strong band at 1180 cm^{-1}. However, this is believed to arise from the hydrazone group.

The NMR spectrum of the *trisethylenethioketal (V)* showed the *t*-butyl groups at 1.16 ppm in $CDCl_3$ and the aromatic protons at 8.20 ppm. The 1,3,5-triacetylbenzene trisethylenethioketal (IX) was prepared in the same way as (V) for a comparison of the spectra. The aromatic protons of (IX) absorbed at 7.98 ppm. The most striking difference between the two NMR spectra is in that part where the ethylene chains in the five-membered ketal rings absorb, see Figs. 1 and 2. In the spectrum of (IX) there is a very close doublet with four small satellites centered at 3.41 ppm, *i.e.* a very strongly

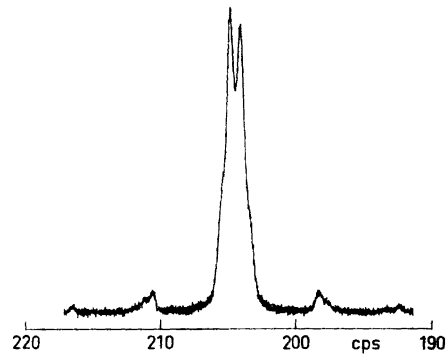


Fig. 1. The ethylenic part of the NMR spectrum (60 MHz, 40°C) of (IX) in deuteriochloroform.

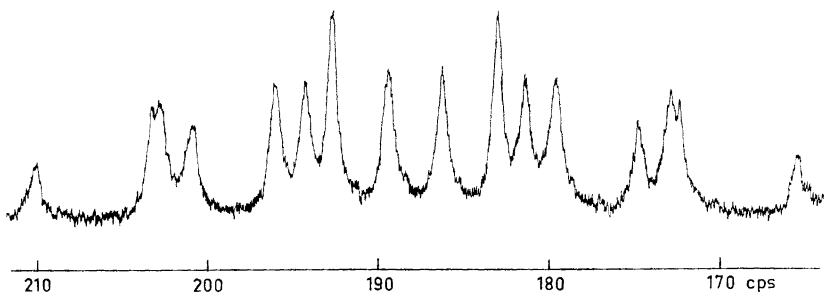


Fig. 2. The ethylenic part of the NMRspectrum (60 MHz, 40°C) of (V) in deuteriochloroform.

coupled AA'BB'-system. In the spectrum of (V) there is a much more weakly coupled AA'BB'-system ranging from 2.75 to 3.50 ppm and centered at 3.13 ppm. Besides the total up-field push there is evidently in this case a greater

difference in chemical shift between the geminal protons in each methylene group. The shift values can be estimated from the spectrum to be 2.99 and 3.26 ppm. Both these effects are explicable if one assumes that the ethylene chains of (V) have been pushed over the ring to a position where they are more influenced by the ring-current. Anisotropy effects from the *t*-butyl group on the same benzylic carbon as well as a *meta*-situated one may also assist, but the direction of these effects is more difficult to predict. There was no temperature dependence of the spectra between −60 and 60°C.

The IR spectrum of (V) in KBr reveals an interesting doubling of the *t*-butyl bands at 1396, 1393 cm^{-1} and 1368, 1362 cm^{-1} that is not observed in any of the other compounds investigated. There are also bands at 1479 and 1582 cm^{-1} that can be attributed to the aromatic ring and a strong band at 1422 cm^{-1} which probably arises from the ethylene chains in the cyclic ketal rings.

1,3,5-Trineopentylbenzene (III). The ultraviolet absorption of (III) in hexane is in good accordance with reported [17] values for other symmetrical trialkylbenzenes. The 271 nm band has an equivalence in triethylbenzene, whereas the bands at 265 and 259 nm agree better with the spectrum of mesitylene.

In the infrared region from 680 to 890 cm^{-1} there are the two expected [17] bands at 742 and 862 cm^{-1}. The former is at a higher frequency than the corresponding one in trialkylbenzenes with α-branching, whereas the other agrees well with the spectrum of triethylbenzene. Bands at 1389, 1364, 1238, and 1202 cm^{-1} are attributable to the *t*-butyl groups. The aromatic 1500 and 1600 cm^{-1} bands appear at 1476 and 1602 cm^{-1}. There is also a band at 1450 cm^{-1} that may originate from the methylene groups.

NMR showed the expected three sharp singlets with relative areas 27:6:3 at 0.90, 2.42, and 6.65 ppm.

Even the mass spectrum was remarkably clean and regular. It showed a parent peak at *m/e* 288, and in the order of increasing height, peaks at *m/e* 232, 176, 120, and 57 (base peak). These can be rationalized by the step-wise loss of *t*-butyl groups (*m/e* 57) with incorporation of a proton, possibly by a McLafferty rearrangement.[18] There is also a rather intense peak at *m/e* 273 (M−15) resulting from the elimination of a methyl group.

The empirical formula $C_{21}H_{36}$ was also confirmed by the elemental analysis.

1,3,5-Tris(2,2-dimethylpropane-1-ol)benzene (VI). The triol analysed well for $C_{21}H_{36}O_3$ and the calculated mass number 336 was established by mass spectroscopy. The parent peak was weak. The peak at *m/e* 279 (M−57), corresponding to the loss of a *t*-butyl group, is the base peak and in fact the only peak over 20 % relative abundance (besides the isotopic contribution to the parent peak).

NMR, measured in deuterated acetone, showed the expected singlets for the *t*-butyl groups and the aromatic protons. The hydroxylic and tertiary benzylic protons appeared as two doublets at 3.91 and 4.35 ppm, respectively, with the coupling constant $J=4$ Hz. The rate of proton exchange is evidently sufficiently slow to permit observation of the spin-spin splitting. By addition of a drop of deuterium oxide the former peak disappeared and the latter changed to a singlet.

1,3,5-Tris(1,2,2-trimethylpropane-1-ol)benzene (VII). The NMR spectrum of (VII) showed some interesting peculiarities. In deuteriochloroform at the probe temperature (40°C) the expected *t*-butyl singlet appeared at 0.94 ppm and a multiplet ranging from 7.25 to 7.45 ppm, attributable to the aromatic protons, was also seen (Fig. 3). There were also two singlets with the areas in the ratio 1:3 at 1.65 and 1.60 ppm. The shape and position of the former were concentration dependent. By addition of a drop of deuterium oxide the peak at 1.65 ppm disappeared and was consequently attributed to the three hydroxylic protons. In deuterated acetone the hydroxylic protons appeared as two peaks at 3.38 and 3.43 ppm, in the ratio 1:2. Other parts of the spectrum were not changed appreciably. Expansion of the spectrum showed the aromatic multiplet to correspond to an AB_2-system with the B-part most deshielded. The difference in chemical shift was 7 Hz in acetone. The value of the coupling constant, 1.8 Hz, is in accord with a *meta* coupling. This implies the astonishing fact that there are two identical protons and one different in a symmetrically trisubstituted benzene derivative with identical substituents. This is explained if one assumes a hindered rotation around the carbon-carbon bonds connecting the ring with the benzylic carbons, and that in most molecules there is one *t*-butyl group on one side and two on the other side of the ring plane.

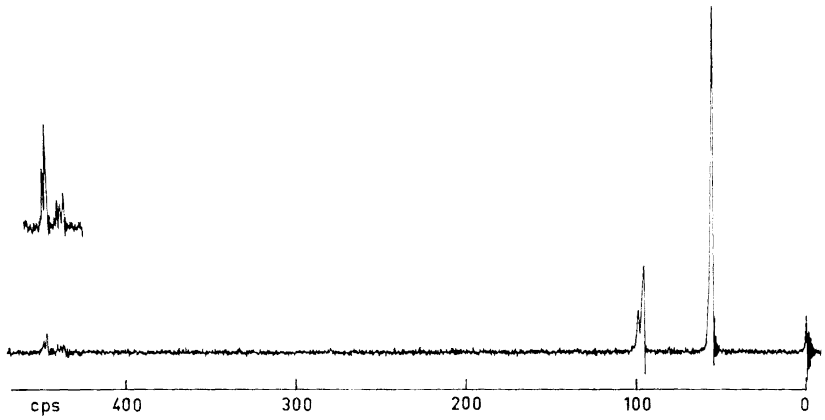
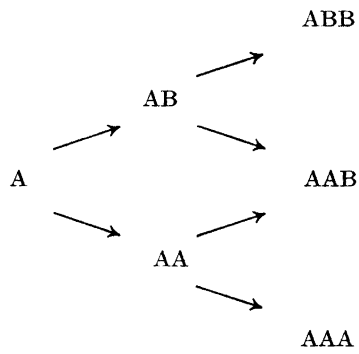


Fig. 3. NMR spectrum (60 MHz, 40°C) of (VII) in deuteriochloroform. The aromatic part is also recorded with five times amplification. The aromatic multiplet is disturbed by the resonance of chloroform at 436 Hz.

That most molecules should be formed in the conformation mentioned above could be made plausible by the following scheme, showing the step-wise Grignard addition to tripivaloylbenzene. A corresponds to a molecule in which one pivaloyl group has reacted. AA has two *t*-butyl groups on the same side of the ring plane and AB has one on each side. Then, AAB≡ABB can be formed in three ways, while the single way leading to AAA is also considered less probable because of steric hindrance to attack on the A side in AA.



As the spectrum of (VI) does not reveal the same appearance of the aromatic region, the rotation around the substituent bonds in (VII) must be hindered in some way by the methyl groups, possibly by the interaction between these and *meta*-situated *t*-butyl groups.

If the explanation advanced above is correct the appearance of the spectrum might be expected to be temperature dependent. This was also shown to be the case. When the aromatic part of the spectrum was recorded at higher temperatures the peaks started to move together. To reach the maximum working temperature of the spectrometer (200°C), the solvent was changed to *N*,*N*-dimethylacetamide, and a sealed tube was used. In Fig. 4, showing the aromatic part of the spectrum, it can be seen that there was still no complete collapse of the AB_2-spectrum at this temperature. Fig. 5 shows the same

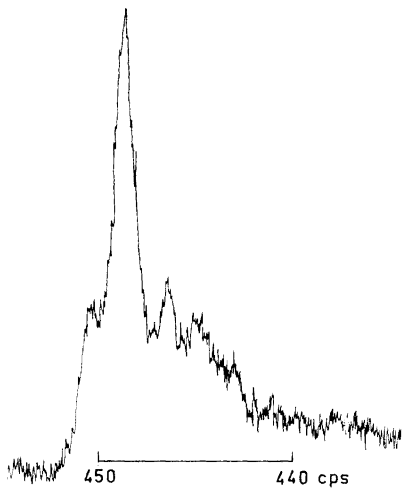


Fig. 4. The aromatic part of the NMR spectrum (60 MHz, 200°C) of (VII) in *N*,*N*-dimethylacetamide.

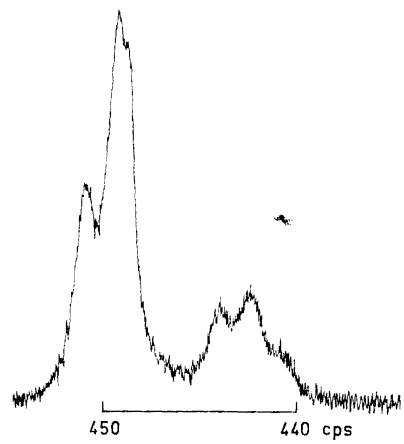


Fig. 5. The aromatic part of the NMR spectrum (60 MHz, 40°C) of (VII) in *N*,*N*-dimethylacetamide.

part of the spectrum recorded at 40°C. From the latter ν_A and ν_B were determined to be 450 and 443 Hz, respectively, with the side-band technique. With the collapse temperature T_c higher than 200°C, $\Delta G_c^{\ddagger}$ can be estimated to be greater than 25 kcal/mole. (T_c=250°C corresponds to $\Delta G_c^{\ddagger}\sim$28 kcal/mole.) These values are calculated from the approximate formulas given by Gutowsky and Holm.[19]

There are, except for compounds with fused alicyclic rings, only two earlier reports in the literature of similar restricted rotation of an alkyl group, attached with an essentially single bond to a benzene ring.* Dix *et al.*[20] reported the Arrhenius activation energy to be 11.5±0.6 kcal/mole for the rotation of the neopentyl groups in 1,2-dineopentyltetramethylbenzene.** This was concluded indirectly from the temperature dependence of the magnetical nonequivalence of the methylene hydrogens. Newseroff and Sternhell[21] reported that there is restricted rotation about the sp^2—sp^3 carbon-carbon bond in di-*t*-butyl *p*-methoxyphenyl carbinol without giving the height of the barrier.

EXPERIMENTAL

The infrared spectra were recorded on a Beckman IR-9 spectrophotometer with potassium bromide pellets, and the positions of the absorption maxima are expressed in wave numbers (cm^{-1}). Band intensities are classified as weak (w), medium (m), strong (s), or very strong (vs). The ultraviolet absorption spectra were recorded on a Cary Model 15 spectrophotometer and the positions of the absorption maxima or shoulders are expressed in nanometers (nm) followed by the corresponding extinction coefficient. Shoulders are denoted by sh. Mass-spectra were obtained at 70 eV on the LKB A 9000 mass spectrometer at the Department of Organic Chemistry of the University of Lund. The most abundant ions are tabulated, followed by the relative abundance in per cent of the base peak. The NMR spectra were recorded on a Varian A-60 spectrometer equipped with a V 6040 variable temperature controller. Peaks are reported in ppm downfield from TMS as internal standard. Peak shapes are noted as singlet (s), doublet (d), triplet (t), quartet (q), and multiplet (m). The elemental analyses were performed by the Scandinavian Microanalytical Laboratory, Herlev, Denmark. Melting points were determined on a Kofler micro hot stage. Gas chromatography was carried out with a Perkin-Elmer F11 gas chromatograph equipped with a flame ionisation detector and the following column: 6 ft×0.125 in. 15 % SE-30 silicon gum rubber on 80—100 Chromosorb W. Percentage composition refers to the relative areas (planimeter integration) observed for the different compounds.

Pivaloylacetaldehyde (I). A mixture of 50 g (0.5 mole) of pinacolone (dried and distilled) and 55.5 g (0.75 mole) of ethyl formate (distilled from calcium hydride) was reacted with 24 g (0.5 mole) of 50 % sodium hydride dispersed in mineral oil, in exact accord with the procedure described for cyclohexanone.[11] Distillation at 60—61 mm gave 39.4 g (66 %) of pivaloylacetaldehyde, b.p. 72—75°C, lit.[9] 80—83°C (75 mm).

NMR (neat): 1.16 (s, 9H, $-C(CH_3)_3$), 3.58 (d, J=3 Hz, keto form, $-CH_2$), 5.72 (d, J=5 Hz, enol form, CH=CH), 7.98 (d, J=5 Hz, enol form, CH=CH), 9.77 (t, J=3 Hz, keto form, —CHO), 14.33 (broad, enol form, —OH).

* *Note added in proof.* After the submission of this paper three other examples of similar restricted rotation have appeared; Schaefer, T., Schwenk, R., Macdonald, C. J. and Reynolds, W. F. *Can. J. Chem.* **46** (1968) 2187 and Pinkus, A. G., Riggs, J. I., Jr. and Broughton, S. M. *J. Am. Chem. Soc.* **90** (1968) 5043 and Cupas, C.A., Bollinger, J.M. and Haslanger, M. *J. Am. Chem. Soc.* **90** (1968) 5502.

** *Note added in proof.* It has been pointed out by Dr. R. E. Carter that the calculated Arrhenius activation energy should be near to 16.2 kcal/mole, corresponding to a collapse temperature of 52°C.

When the residue in the distillation flask was kept for some days at room temperature, it solidified. Distillation afforded 2.4 g of raw product, later identified as tripivaloylbenzene, b.p. 160–165°C (2 mm).

Treatment of the sodium salt of pivaloylacetaldehyde with ethanolic hydrogen chloride. Ethoxymethylenepinacolone (VIII). The sodium salt was treated with ethanolic hydrogen chloride for the purpose of obtaining pivaloylacetaldehyde diethylacetal. (According to reports in the literature,[22] refluxing this acetal in water could be expected to give 1,3,5-tripivaloylbenzene.) The product was shown to be ethoxymethylenepinacolone, however. This product might have been formed either by a direct etherification of the enol form of the aldehyde or from an intermediate diethylacetal by elimination of a molecule of ethanol.

An ether solution of the sodium salt, prepared as above [11] except for the hydrolysis step from 50 g (0.5 mole) of pinacolone, was evaporated on the aspirator. Ethanol (138 g, 99.5 %, 3 moles) was added to the solid salt followed by the addition of a solution of 38.4 g (1.05 moles) of anhydrous hydrogen chloride in 92 g (2 moles) of 99.5 % ethanol. The temperature rose to 50°C, where it was kept by stirring and occasional external cooling for 3 h. A saturated solution of potassium hydroxide in 99.5 % ethanol was added until neutral reaction to litmus. The precipitated salts were removed by filtration and the filtrate was dried over anhydrous magnesium sulphate. The ethanol was evaporated on a steam-bath and the residue was distilled *in vacuo*. The fraction boiling between 97 and 102°C (10 mm) was collected. It weighed 9.3 g (12 %) and had a purity of > 96 % (GLC). Lit.[23] b.p. 103–104°C (16 mm).

NMR (neat): 1.16 (s, 9H, $-C(CH_3)_3$), 1.35 (t, 3H, $-CH_3$), 4.06 (q, 2H, $-CH_2$), 6.05 (d, $J=12$ Hz, 1H, CH=CH), 7.65 (d, $J=12$ Hz, 1H, CH=CH).

1,3,5-Tripivaloylbenzene (II)

a) Acidic catalysis. Pivaloylacetaldehyde (5.0 g, 0.039 mole) was refluxed in 10 ml of acetic acid for 1 h. Careful evaporation of the acetic acid and unreacted pivaloylacetaldehyde (~3 g) left a residue that solidified in the flask. It was dissolved in ethanol treated with activated carbon and filtered hot through celite. The hot ethanol solution was diluted with water until faint clouding and cooled in the refrigerator, whereupon light yellow crystals precipitated. Yield 1.4 g (30 %). M.p. 75–78°C. After several recrystallizations from ethanol the white glistening crystals melted at 79.5–80.5°C. (Found: C 76.28; H 9.08. Calc. for $C_{21}H_{30}O_3$: C 76.32; H 9.15).

The same yield was obtained on refluxing for 7 h.

Mass spectrum: 330(0.7), 287(4), 275(5), 274(29), 273(100), 246(14), 57(57), 43(5), 41(22), 39(4), 29(20), 28(14), 18(9).

IR-spectrum: 2988m, 2940m, 2876m, 1678s, 1590m, 1474m, 1427m, 1397m, 1370m, 1266m, 1216w, 1202w, 1144s, 1056m, 1010m, 936w, 918m, 836w, 740m, 597m.

UV-spectrum (ethanol): 316(sh, 400), 290(620), 247(sh, 7500), 222(30 500).

NMR (CCl_4): 1.39 (s, 27H, $-C(CH_3)_3$), 8.16 (s, 3H, aromatic).

UV-spectrum of 1,3,5-triacetylbenzene (ethanol): 321(sh, 160), 292(550), 246(sh, 3600), 226(56 800).

b) Knoevenagel catalysis (preferred procedure). Pivaloylacetaldehyde (20.0 g, 0.156 mole), piperidine (2.13 g, 2.5 ml, 0.025 mole), acetic acid (1.50 g, 1.43 ml, 0.025 mole) and toluene (50 ml) were boiled under reflux using a Dean-Stark water separator. After 5–7 h 90–100 % of the theoretical amount of water had separated. The cooled solution was washed with, in order, water, 10 % hydrochloric acid, 1 M sodium carbonate and water. After evaporation of the toluene, the residual red oil was distilled at 150–160°C (1–2 mm), yielding about 9 g of crystalline product. After one recrystallization from ethanol there remained 7.0 g (40 %) of light yellow crystals, m.p. 79–80°C.

Because the distillation step in the synthesis of the pivaloylacetaldehyde also afforded some tripivaloylbenzene, the Knoevenagel condensation once was carried out with undistilled β-ketoaldehyde. However, the yield was lower in that experiment than the total yield from the distillation of pivaloylacetaldehyde plus the trimerization of the purified aldehyde.

1,3,5-Trineopentylbenzene (III)

1,3,5-Tripivaloylbenzene trihydrazone (IV). A mixture of 3.30 g (10 mmoles) of 1,3,5-tripivaloylbenzene and 6 g (0.1 mole) of 85 % hydrazine hydrate was refluxed in 15 ml of ethanol for 6 h. Cooling over night afforded 3.6 g (97 %) of (IV) as white crystals that were filtered off and dried in a vacuum desiccator, m.p. 148–149°C.

IR-spectrum: 3364s, 3282w, 3244w, 2965vs, 2905m, 2865m, 1633w, 1584m, 1481s, 1462m, 1391m, 1360s, 1203w, 1180s, 1088m, 1020w, 888m, 852m, 794m, 732m, 566w.

NMR ($CDCl_3$): 1.15 (s, 27H, $-C(CH_3)_3$), 4.73 (broad, 6H, $-NH_2$), 6.88 (s, 3H, aromatic).

By using butanol as solvent the reaction time was reduced to 2 h but slightly lower yields were obtained possibly depending upon a higher solubility of the product in this alcohol.

Wolff-Kishner reduction of the trihydrazone (IV). A mixture of 3.6 g (9.7 mmoles) of the preceding compound, 8.4 g of potassium hydroxide, and 54 ml of anhydrous ethylene glycol (distilled from sodium) was heated carefully on an oil bath to dissolve the base. The temperature was raised to 140°C where gas evolution started, and after it had ceased the temperature was raised to 190°C, where it was kept for 5 h. Throughout the reaction a white solid sublimed into the condenser. To the residue in the reaction flask 50 ml of water was added. Extraction with three 50 ml portions of ether, washing the ether phase with 50 ml of water, drying the former over anhydrous magnesium sulphate and evaporation yielded 1.02 g of slightly yellow substance, m.p. 76.0–76.5°C. The sublimed white product in the condenser was recovered by means of carbon tetrachloride. It weighed 1.06 g and melted at 77–78°C. Total yield of (III) was 2.08 g (75 %).

An attempt to carry out the reduction step at room temperature by the use of freshly sublimed potassium *t*-butoxide in anhydrous dimethylsulphoxide [24] was unsuccessful.

Several recrystallizations from ethanol raised the melting point of (III) to 77.5–78.5°C. (Found: C 87.40; H 12.60. Calc. for $C_{21}H_{36}$: C 87.42; H 12.58).

Mass spectrum: 290(1), 289(7), 288(35), 274(6), 273(27), 233(8), 232(44), 231(34), 177(10), 176(67), 175(11), 161(4), 145(4), 121(10), 120(89), 119(13), 118(4), 117(5), 106(5), 105(7), 91(6), 71(13), 58(5), 57(100), 55(4), 43(16), 41(24), 39(27), 29(19).

IR-spectrum: 3014w, 2950vs, 2860m, 1602m, 1476s, 1450m, 1389m, 1364s, 1238m, 1202w, 862m, 742m.

UV-spectrum (hexane): 271(210), 265(250), 259(sh, 9200), 217(sh, 10 900), 203(57 800), 199(54 400).

NMR (CCl_4): 0.91 (s, 27H, $-C(CH_3)_3$), 2.43 (s, 6H, $-CH_3$), 6.68 (s, 3H, aromatic).

1,3,5-Tripivaloylbenzene trisethylenethioketal (V). A hot solution of 1.08 g (3.27 mmoles) of 1,3,5-tripivaloylbenzene and 5 ml of ethanedithiol (Fluka, purum) in 50 ml of acetic acid was treated drop-wise with 6 ml of boron trifluoride ethyletherate (Fluka, pract. ~48 % BF_3) and left over night for crystallization. After cooling white crystals separated. They were filtered off and recrystallized by dissolution in hot xylene and precipitation by 99.5 % ethanol. Yield 1.17 g (64 %), m.p. 266–267°C.

More crystalline substance precipitated from the mother liquor but was not collected.

IR-spectrum: 2976s, 2958s, 2926s, 2870m, 1583m, 1479m, 1466m, 1422s, 1396m, 1393m, 1368m, 1362m, 1212m, 1150m, 879w, 801w, 793w, 718w, 665m.

NMR ($CDCl_3$): 1.16 (s, 27H, $-C(CH_3)_3$), 3.13 (m, 12H, $-SCH_2CH_2S-$), 8.20 (s, 3H, aromatic).

1,3,5-Triacetylbenzene trisethylenethioketal (IX) was prepared by the method described above. M.p. 111.0–112.5°C.

NMR ($CDCl_3$): 2.15 (s, 9H, $-CH_3$), 3.41 (m, 12H, $-SCH_2CH_2S-$), 7.98 (s, 3H, aromatic).

Desulphurization of the trisethylenethioketal (V). The desulphurization was carried out with Raney nickel made by the simplified procedure reported in a recent monograph [25] from 66 g of nickel-aluminium alloy. A solution of 1.01 g (1.81 mmoles) of (V) in 50 ml of ethanol was refluxed with stirring for 1 h with the specified amount of Raney nickel. The catalyst was filtered off and the reaction mixture was diluted with 250 ml of water. The aqueous solution was extracted with 50 ml of petroleum ether three times. The combined organic phases were dried over anhydrous magnesium sulphate and the solvent was evaporated leaving a white solid. After one recrystallization from 99.5 % ethanol

there remained 0.47 g (90 %) of 1,3,5-trineopentylbenzene that was pure according to GLC (> 99 %).

Clemmensen reduction of 1,3,5-tripivaloylbenzene. Amalgamated zinc was prepared according to a known method [26] from 20 g of mercuric chloride and 100 g of zinc dust, previously washed with 5 % hydrochloric acid. Part of this amalgam, 10 g, was covered with 5 ml of water and 0.1 ml of acetic acid. A solution of 0.68 g (2.06 mmoles) of 1,3,5-tripivaloylbenzene in 5 ml of toluene was added and the mixture was refluxed briskly for 10 h with the addition of a 2 ml portion of conc. hydrochloric acid every hour. After addition of another 10 g of amalgamated zinc and 7.5 ml of conc. hydrochloric acid the mixture was refluxed for 20 h more. After cooling the mixture was extracted with 15 ml of ether. The organic phase was washed with two 5 ml portions of water and dried over Sikkon (Fluka). Evaporation left an oily residue that was analysed by GLC. It consisted of four components in the proportions (in the order of increasing retention time) 15:30:37:18. The compound with the shortest retention time was indicated by GLC and NMR to be 1,3,5-trineopentylbenzene (see text).

Huang-Minlon-Wolff-Kishner reduction of 1,3,5-tripivaloylbenzene. A mixture of 3.40 g (10.3 mmoles) of 1,3,5-tripivaloylbenzene, 4.8 g of potassium hydroxide and 3.25 ml of 85 % hydrazine hydrate was refluxed at 140°C until the gas evolution ceased. Continued refluxing with separation of the water formed by a Dean-Stark trap raised the temperature to 180°C where it was kept for 3 moore hours. The mixture was allowed to cool over night whereupon 25 ml of water was added and the mixture extracted twice with 50 ml of ether. After washing with 50 ml of water the combined ether phases were dried over anhydrous magnesium sulphate and evaporated. The tough, white residue was dissolved in the minimum amount of ethanol and yielded after cooling 0.4 g of a white solid. NMR indicated that this product mixture contained tripivaloylbenzene derivatives with carbonyl groups as well as hydrazone groups and neopentyl groups in different amounts in the molecules.

Carbinols derived from 1,3,5-tripivaloylbenzene

1,3,5-Tris(2,2-dimethylpropane-1-ol)benzene (VI). 1,3,5-Tripivaloylbenzene (1.0 g, 3.0 mmoles), was dissolved in 35 ml of 99.5 % ethanol. To this solution 0.1 g of 10 % palladium on charcoal was added and hydrogenation was carried out in a Parr low-pressure hydrogenator at room temperature. After the theoretical amount of hydrogen had been adsorbed the catalyst was filtered off with the help of celite. Evaporation yielded a crystalline solid that after recrystallization from ethanol-water weighed 0.6 g (60 %), m.p. 214–215°C. (Found: C 74.94; H 10.64. Calc. for $C_{21}H_{36}O_3$: C 74.95; H 10.78).

IR-spectrum: 3450vs, broad, 2984s, 2968s, 2936m, 2892m, 2872m, 1608w, 1480m, 1470m, 1462m, 1395m, 1368s, 1267s, 1240w, 1215m, 1196m, 1164m, 1061s, 1050m, 1012s, 924w, 884m, 798m, 774m, 667m, 590m, broad, 540m, broad, 475w.

Mass spectrum: 336(0.2), 281(3), 280(20), 279(100), 277(4), 205(4), 193(4), 156(9), 91(4), 87(7), 69(6), 57(14), 43(5), 41(8), 29(5).

NMR (CD_3COCD_3): 0.92 (s, 27H, $-C(CH_3)_3$), 3.91 (d, 3H, $J=4$ Hz, $-OH$), 4.35 (d, 3H, $J=4$ Hz, $-CH$), 7.18 (s, 3H, aromatic).

When the hydrogenation was made with the addition of 0.1 ml of 70 % perchloric acid [27] the same product (VI) was isolated and none of the expected hydrocarbon.

1,3,5-Tris(1,2,2-trimethylpropane-1-ol)benzene (VII). Methyl magnesium iodide was prepared from 5.98 g (0.042 mole) of methyl iodide (Fluka, purum) and 1.03 g of magnesium in ether. The ether solution was concentrated by distilling off the ether under normal pressure at a bath temperature of 100°C. In a 500-ml flask equipped with a stirrer, condenser, dropping funnel and gas inlet tube for nitrogen 2.34 g (7.08 mmoles) of 1,3,5-tripivaloylbenzene was dissolved in 50 ml of ether. The drop-wise addition of the Grignard solution precipitated a red complex. To facilitate stirring the ether was driven off and replaced by 75 ml of benzene, whereupon most of the material went into solution. The temperature was kept at 70°C during the addition of the rest of the Grignard reagent (about 1 h). The reaction mixture was refluxed for 6 h. It was neutralized with a saturated ammonium chloride solution. The benzene phase was separated off and dried over anhydrous sodium sulphate. The water layer was extracted with ether continuously

during 24 h but evaporation of the ether phase did not leave a residue. The benzene phase, however, yielded 2.0 g of a white solid on evaporation. Crude yield 75 %. Recrystallization from methanol-water gave the pure compound, m.p. 139–140°C. The purity was tested by thin-layer chromatography on silica (Merck G) with ethyl acetate as developer.

IR-spectrum: 3450s, broad, 2976s, 2910m, 2874m, 1598w, 1483m, 1470m, 1457m, 1440m, 1394m, 1372s, 1231m, 1178m, 1125s, broad, 1034m, 1008m, 924m, 888m, 818m, 731w, 721w, 636w, broad, 585w, broad, 522w, broad.

NMR ($CDCl_3$): 0.94 (s, 27H, $-C(CH_3)_3$), 1.65 (s, broad, 3H, $-OH$), 1.60 (s, 9H, $-CH_3$), 7.28 (d, 1H, $J=2$ Hz, aromatic), 7.43 (d, 2H, $J=2$ Hz, aromatic).

NMR (CD_3COCD_3): 0.94 (s, 27H, $-C(CH_3)_3$), 1.58 (s, 9H, $-CH_3$), 3.38 (s, 1H, $-OH$), 3.43 (s, 2H, $-OH$), 7.42 (d, 1H, $J=2$ Hz, aromatic), 7.52 (d, 2H, $J=2$ Hz, aromatic).

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