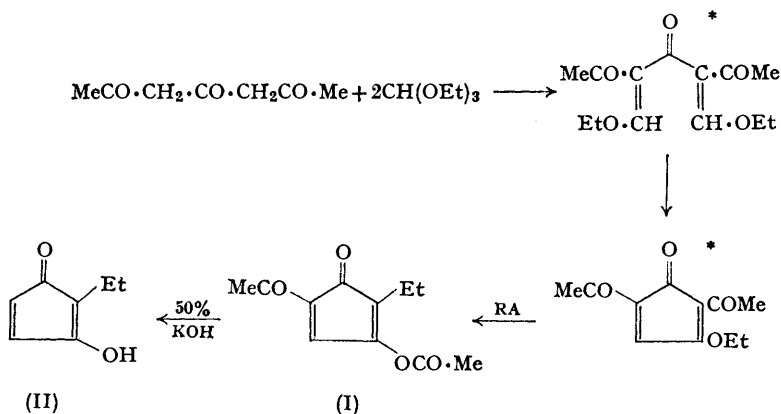


1081. Condensation of Diacetylacetone with Ethyl Orthoformate.

By A. K. KIANG and (MRS.) S. F. TAN.

The reaction of diacetylacetone with ethyl orthoformate in the presence of acetic anhydride gives 3-acetyl-2,4,6-triacetylphenol and 4-acetoacetyl-2,6-diacetyl-3-methylphenol. These are converted by aqueous 50% potassium hydroxide into 2,4-diacetyl-6-methylnaphthalene-1,8-diol and 3-methyl-2,4,6-triacetylphenol, respectively.

KAUSHAL¹ condensed diacetylacetone with ethyl orthoformate in the presence of a small quantity of acetic anhydride and isolated a substance, $C_{11}H_{12}O_4$, m. p. 106° , which gave, with 50% aqueous potassium hydroxide, a yellow compound, $C_7H_8O_2$, m. p. 177° , forming a monoacetate, m. p. 135° . Based on the analyses, he proposed structures (I) and (II), respectively, for these compounds, and suggested that they were formed according to the scheme shown, involving an unusual rearrangement.



* Not isolated; RA = rearrangement.

Interest in such cyclopentadienone derivatives led us to repeat Kaushal's investigations. We found, contrary to his report, that the reaction, under the conditions used by him, gave two isomeric phenols, $C_{15}H_{16}O_5$, (III) and (IV), m. p.'s 184° and 108° , respectively, in yields of 5 and 39%, respectively. The yields were about the same with diacetylacetone and ethyl orthoformate in the molar ratio of 1:1 or 1:2. In the absence of acetic anhydride, only a small amount of 2,6-dimethylpyrone was isolated. On the other hand, acetic anhydride (1 mol.) considerably lowered the yields of the products and produced much resinous material.

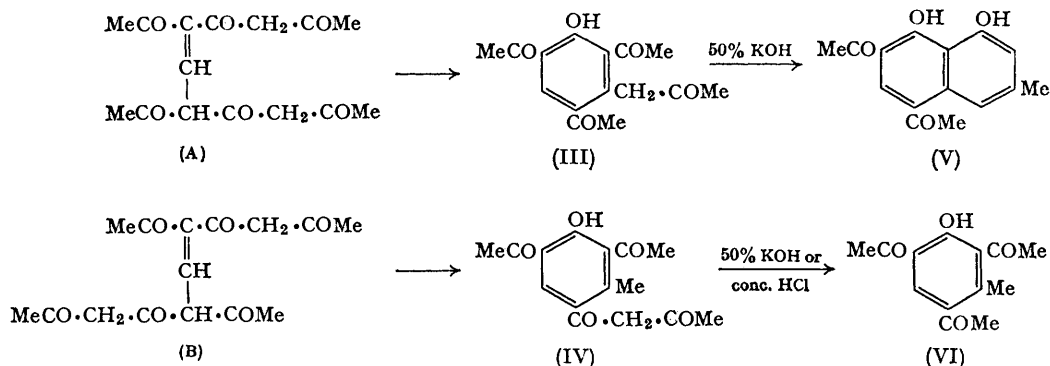
Both phenols are insoluble in water, slightly soluble in aqueous sodium carbonate, and readily soluble in dilute aqueous sodium hydroxide. An ethanolic solution of either gives a red coloration with ferric chloride solution. Phenol (IV) is much more soluble in benzene than is phenol (III).

When heated with 50% aqueous potassium hydroxide, the phenols give rise to potassium salts from which compounds (V), canary-yellow needles, m. p. 177° , and (VI), colourless needles, m. p. 131° , are isolated, respectively. Compound (IV) is also converted into compound (VI) by heating with concentrated hydrochloric acid.

The ultraviolet spectra of the compounds in ethanol, λ_{max} . ($\log \epsilon$), are as follows: (III), 245 (4.40), 321 (4.02); (IV), 242 (4.27), 303 (4.23); (V), 258 (4.48), 279 (3.73) (infl.), 382 (4.27); (VI), 241 (4.43), 317 (3.90). These show that compound (V) is a naphthalene derivative whilst the others are benzene derivatives.

¹ R. Kaushal, *J. Indian Chem. Soc.*, 1947, **24**, 189.

Phenols (III) and (IV) are each derived from condensation between 2 mols. of diacetylacetone and 1 mol. of ethyl orthoformate² to give intermediates (A) and (B), followed by cyclic dehydration. Their structures are confirmed by their infrared spectra. Both compounds show broad weak absorption maxima (KBr disc) in the region 3100—2400 cm.⁻¹ (chelated OH); and maxima in Nujol at 1600 and 1570 (aromatic-conjugated), 1680 (aryl CO), and 1640 cm.⁻¹ (chelated aryl CO); in addition, phenol (III) shows a strong sharp band at 1720 cm.⁻¹, characteristic of an aliphatic open-chain ketone, and phenol (IV), a strong broad band centred at 1610 cm.⁻¹, characteristic of a β -diketone.



Compound (V) is formed from phenol (III) by intramolecular Claisen condensation. Its infrared spectrum in Nujol shows (i) the disappearance of the $\text{CH}_2\cdot\text{CO}\cdot\text{CH}_3$ group, (ii) lowering of the carbonyl frequency to 1670 cm.⁻¹ [1680 cm.⁻¹ for phenol (III)], and (iii) increase in the aromatic frequency to 1603 and 1577 cm.⁻¹ [1597 and 1570 cm.⁻¹ for phenol (III)], consistent with the change from benzenoid to naphthalenoid structures.

Of the four possible products, we think the 1,8-diol structure (V) is correct, as a solution of the compound in 0.5M-boric acid produces an augmentation of conductivity to an extent comparable with that of naphthalene-1,8-diol.³ A solution of it in 0.05M-borax buffer develops a green colour with Gibbs's reagent (quinonechloroimide), showing that the position *para* to the phenolic group is probably free.⁴ Moreover, the infrared spectrum of the compound (KBr disc) shows a very weak broad band centred at 3100 cm.⁻¹, indicating hydrogen bonding. This absorption in chloroform solution does not decrease in intensity with dilution, indicating the absence of intermolecular hydrogen bonding which would be expected in the alternative products.

Compound (V) gives a green colour with ferric chloride and forms a pale yellow monoacetate, m. p. 202°, which is sparingly soluble in cold 10% aqueous sodium hydroxide and gives a green colour with ferric chloride. Attempts to prepare the diacetate were unsuccessful. The monoacetate gives no colour with Gibbs's reagent, showing probably that the 8-hydroxy-group in (III) has been preferentially acetylated. A molecular model of compound (V) shows that the 1-hydroxy-group is sterically hindered.

Compound (VI) is derived from compound (IV) by hydrolysis of the β -diketone. The infrared absorptions due to chelated OH, free and chelated aryl ketone, and aromatic groups are very similar in compounds (IV) and (VI) except for the disappearance of the β -diketone absorption in compound (VI).

Compound (VI) is soluble in 10% aqueous sodium carbonate solution. Its ethanolic solution gives a deep-red colour with ferric chloride. It forms an acetate, m. p. 118°; a

² L. Claisen, *Ber*, 1893, **26**, 2729; *Annalen*, 1897, **297**, 16; H. W. Post, "The Chemistry of Aliphatic Ortho-esters," Reinhold, New York, 1943, p. 69.

³ J. Böeseken, *Rec. Trav. chim.*, 1939, **58**, 3.

⁴ H. D. Gibbs, *J. Biol. Chem.*, 1927, **72**, 650.

methyl ether, m. p. 81—82°; a trioxime, m. p. 244—245°; and a bis-2,4-dinitrophenylhydrazone, m. p. 269° (decomp.). The non-formation of the trisdinitrophenylhydrazone may be attributed to the hindered nature of the 2-carbonyl group.

EXPERIMENTAL

Diacetylacetone was prepared from dehydroacetic acid by the method of Collie and Reilly.⁵

Condensation between Diacetylacetone and Ethyl Orthoformate.—A mixture of diacetylacetone (7.1 g.), ethyl orthoformate (7.4 g.), and acetic anhydride (1.2 c.c.) was refluxed gently on a sand-bath (4½ hr.). This was cooled and kept in a refrigerator for 2 days. The crystals that formed were filtered off and washed with a small amount of ether. Two recrystallisations from benzene gave almost colourless crystals of 3-acetonyl-2,4,6-triacetylphenol (III) (5%), m. p. 184—185° (Found: C, 65.3, 65.4; H, 6.0, 6.1. C₁₅H₁₆O₅ requires C, 65.2; H, 5.8%).

The filtrate from the first crop was mixed with an equal volume of water and allowed to stand overnight. The crystals (2nd crop) were filtered off and two recrystallisations from ethanol gave almost colourless crystals of 4-acetoacetyl-2,6-diacetyl-3-methylphenol (IV) (39%), m. p. 108° [Found: C, 65.3, 65.3; H, 5.9, 6.0%; M, (Rast) 265, 254. C₁₅H₁₆O₅ requires C, 65.2; H, 5.8%; M, 276].

Slow evaporation of the filtrate from the second crop of crystals gave impure mixtures containing both phenols, the separation of which was effected by means of fractional recrystallisation from benzene in which phenol (IV) is more soluble, or by extracting an ether solution of the mixture with saturated aqueous sodium hydrogen carbonate solution in which compound (IV) is more soluble.

Hydrolysis of Compound (III).—The phenol (0.85 g.) was warmed with 50% aqueous potassium hydroxide (8 c.c.) with occasional stirring on a water-bath for 1½ hr. The resulting paste was cooled in ice and acidified with dilute hydrochloric acid. The solid was filtered off, washed with cold water, and recrystallised from ethanol, giving canary yellow crystals (96%) of 2,4-diacetyl-6-methylnaphthalene-1,8-diol (V), m. p. 177° (Found: C, 69.6, 69.85; H, 5.65, 5.7; C-Me, 15.8. C₁₅H₁₄O₄ requires C, 69.75; H, 5.5; 3C-Me, 17.5%).

A mixture of this compound (0.2 g.) and acetic anhydride (1 c.c.) was heated under reflux for 2 hr. This was cooled in ice and the solid that separated out was filtered off. Recrystallisation from ethanol or benzene gave pale yellow needles of the *monoacetate*, m. p. 202—203° (Found: C, 67.95, 67.6; H, 5.4, 5.6. C₁₇H₁₆O₅ requires C, 68.0; H, 5.4%).

Effect of Compound (V) on the Conductivity of Boric Acid Solution.—The specific conductivities of (a) 0.5M-boric acid solution, (b) a 0.0001M-solution of compound (V) in water, and (c) a 0.0001M-solution of compound (V) in 0.5M-boric acid solution were measured at 22° in glass cells with platinised electrodes, using a Tinsley conductivity bridge and Crossor double-beam oscillograph. The average values obtained were (a) 29.3 × 10⁻⁶; (b) 5.0 × 10⁻⁶; and (c) 46.0 × 10⁻⁶ ohm⁻¹ cm.⁻¹. The augmentation of conductivity was therefore 12.7 × 10⁻⁶ ohm⁻¹ cm.⁻¹. Calculated from figures obtained by Böeseken,³ 0.0001M-solutions of naphthalene-1,8-diol in 0.5M-boric acid solution give augmentation of conductivity of 13.2—13.6 × 10⁻⁶ ohm⁻¹ cm.⁻¹.

Hydrolysis of Compound (IV).—The phenol (2 g.) was warmed with 50% aqueous potassium hydroxide (20 c.c.) on a water-bath for 1½ hr. After cooling, the potassium salt was filtered off. A solution of the solid in minimum amount of water was acidified with concentrated hydrochloric acid. The precipitate (100%), after filtration and recrystallisation from ethanol (charcoal), gave colourless needles of 2,4,6-triacetyl-3-methylphenol (VI), m. p. 131° [Found: C, 66.7, 66.9; H, 6.0, 6.1; C-Me, 23.1%; M, (Rast), 219. C₁₃H₁₄O₄ requires C, 66.65; H, 6.0; 4 C-Me, 25.7%; M, 234].

The phenol (VI) (0.1 g.) was gently refluxed with acetic anhydride (1.5 c.c.) for 3 hr. The cooled mixture was poured into water and the precipitate was filtered off. Recrystallisation from benzene—light petroleum (b. p. 50—70°) yielded colourless crystals of the *acetate*, m. p. 118° (Found: C, 65.3, 65.6; H, 5.9, 6.0. C₁₅H₁₆O₅ requires C, 65.2; H, 5.85%).

A mixture of the phenol (VI) (0.8 g.), dimethyl sulphate (2 c.c.), anhydrous potassium carbonate (7 g.), and dry acetone (20 c.c.) was refluxed on a water-bath for 2½ hr. After cooling in ice, the excess potassium carbonate was filtered off and the acetone was distilled off. The oily residue, kept overnight over potassium hydroxide in a desiccator, solidified on rubbing.

⁵ J. N. Collie and A. A. B. Reilly, *J.*, 1922, **121**, 1984.

[1964]

Haslam, Naumann, and Britton.

5649

Recrystallisation from light petroleum (b. p. 50—70°) (charcoal) yielded colourless crystals of the *methyl ether*, m. p. 81—82° (Found: C, 67.7; H, 6.7. $C_{14}H_{16}O_4$ requires C, 67.7; H, 6.5%).

A solution of hydroxylamine hydrochloride (2 g.) in water (5 c.c.) was added to that of the phenol (VI) (0.2 g.) in 10% aqueous sodium hydroxide (8 c.c.), and ethanol (6 c.c.) was added to give a clear solution. The mixture was refluxed on a water-bath for 1 hr. and filtered to remove some gelatinous precipitate. The filtrate, on standing, deposited a precipitate, which yielded almost colourless crystals of the *trioxime*, m. p. 244—245° (from ethanol) (Found: C, 55.5; H, 6.4; N, 15.4. $C_{13}H_{17}N_3O_4$ requires C, 55.9; H, 6.1; N, 15.05%).

Brady's reagent (5 c.c.) was added to a solution of phenol (VI) (0.1 g.) in methanol (3 c.c.), and the mixture heated on a water-bath for 15 min. The red precipitate that formed was filtered off, rubbed with dilute aqueous sodium hydroxide, and washed with water. Continuous extraction of the solid wrapped in filter paper and addition of light petroleum (b. p. 50—70°) to the extract gave red crystals of the *bis-2,4-dinitrophenylhydrazone*, m. p. 269° (decomp.) (Found: C, 50.0; H, 3.8; N, 17.5. $C_{25}H_{22}N_8O_{10}$ requires C, 50.5; H, 3.7; N, 18.85%).

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CHEMISTRY DEPARTMENT, UNIVERSITY OF SINGAPORE.

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