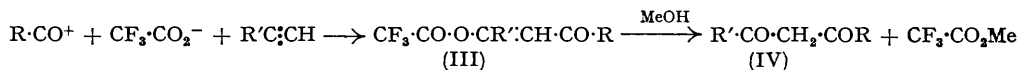
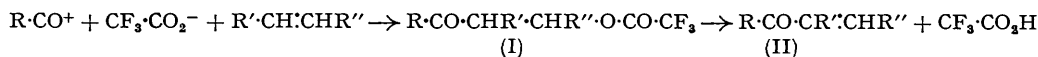


730. *A New Synthesis of 1:3-Diketones and the Preparation of 1-Keto-olefins by Means of Trifluoroacetic Anhydride as Condensing Agent.*

By A. L. HENNE and J. M. TEDDER.

Solutions of carboxylic acids in trifluoroacetic anhydride, when treated with an olefin or an acetylene, yield β -trifluoroacetoxy-ketones (I) or the enol trifluoroacetate of a β -diketone (III), respectively. These compounds are then readily converted into acyl-olefins (II) or β -diketones (IV).

It has been suggested that esterification of, and synthesis of aromatic ketones from, carboxylic acids in trifluoroacetic anhydride solution are effected by acylium ions ($R\cdot CO^+$), small amounts of which occur therein (Bourne, Randles, Tatlow, and Tedder, *Nature*, 1951, **168**, 949). In conformity, it has now been found possible to add the unsymmetrical anhydride ($R\cdot CO\cdot O\cdot CO\cdot CF_3$) across double and triple bonds, simply by introducing olefins and acetylenes into these solutions.



The first products of the addition to olefins, the β -trifluoroacetoxy-ketones (I), have not been obtained pure; they decompose slowly but spontaneously to the acyl-olefins (II). As a method for the preparation of acyl-olefins it is considerably more convenient than Darzens's (*Compt. rend.*, 1910, **150**, 707) in which the olefin is treated with an acyl chloride and a Lewis acid, the intermediate product being treated with a tertiary amine, and our yields are as good (cf. Royals and Hendry, *J. Org. Chem.*, 1950, **15**, 1151). For a general reaction the carboxylic acid is dissolved in trifluoroacetic anhydride, the olefin added, and the reactants left at room temperature for 2—12 hr. The mixture is poured into aqueous sodium carbonate which rapidly releases the free acyl-olefin, and the trifluoroacetic acid can be recovered from the mother-liquor.

The addition to an acetylene has been carried out under much the same conditions. The first product, the enol trifluoroacetate (III) of a β -diketone, is much more stable than the ketol trifluoroacetate (I) and can be obtained pure. In practice it is better simply to pour the mixture into an excess of methyl alcohol and reflux this solution. Transesterific-

ation is very rapid, and the pure β -diketone is obtained by fractionation. The yields reported below are only of the order of 20%, but there is reason to believe that these might be improved.

Neither reaction has been developed exhaustively, but the preparations reported below seem to indicate a scope similar to that of the esterification and aromatic ketone syntheses (Bourne, Stacey, Tatlow, and Tedder, *J.*, 1949, 2976; 1951, 718). The preparation of acyl-olefins by use of trifluoroacetic anhydride, like the reactions reported previously, provides an extremely simple and mild method of performing a well-established reaction. The synthesis of β -diketones directly from carboxylic acids and acetylenes provides a new route to these important compounds.

EXPERIMENTAL

cycloHexenyl Methyl Ketone.—(a) *cycloHexene* (18.5 c.c.) was added to a solution of acetic acid (10.5 c.c.) in trifluoroacetic anhydride (27.0 c.c.). A yellow colour developed rapidly and the temperature rose to, and remained at, 37° for about 1 hr., during which the colour deepened. After a total of 2.5 hr. the mixture was poured on crushed ice and sodium hydrogen carbonate. The product was extracted with ether and dried (MgSO_4). Evaporation left a brown sweet-smelling liquid which contained fluorine. The principal fraction (13.5 g.) boiled at 94—98°/33 mm., and had n_D^{20} 1.4605, d_4^{27} 1.021. This proved to be a 3 : 2 mixture of *cyclohexenyl methyl ketone* and 2-acetyl*cyclohexyl* trifluoroacetate. Treatment with 0.1N-sodium hydroxide converted it all into the olefinic ketone (48.1%), b. p. 86—88°/28 mm., n_D^{20} 1.4885. The semicarbazone had m. p. 217—219°. Kon (*J.*, 1926, 1801) reported b. p. 81°/13 mm., n_D^{20} 1.49042, and for the semicarbazone m. p. 217°.

(b) *cycloHexene* (10.1 c.c.) was treated with trifluoroacetic anhydride (14.2 c.c.) and acetic acid (5.7 c.c.). After 2.5 hr. the mixture was poured into water (instead of sodium hydrogen carbonate solution), and the products were extracted with ether, washed repeatedly with water and finally dilute sodium hydrogen carbonate solution, and dried (MgSO_4). After evaporation, the principal fraction (b. p. 58—62°/6 mm., n_D^{20} 1.4450), was a sweet-smelling, and initially a colourless and neutral liquid. It gradually darkened and soon became strongly acid. This fraction (6.3 g.) was refluxed with methyl alcohol (10 c.c.) for 1.5 hr. The low-boiling material (b. p. 52—63°) was then distilled off, collected, and treated with gaseous ammonia. Evaporation of the excess of methyl alcohol left crude trifluoroacetamide, m. p. 69—70°. The residual high-boiling material was distilled, and the first few drops of distillate were cloudy and consisted partly of water. The main fraction (b. p. 56°/2.5 mm., n_D^{24} 1.4878; 3.83 g.) was *cyclohexenyl methyl ketone*.

cycloHexenyl Propyl Ketone.—Butyric acid (9.2 c.c.) was added to trifluoroacetic anhydride (14.0 c.c.) and *cyclohexene* (10.1 c.c.). The mixture became very warm and darkened rapidly, and it was cooled in water (12°) until the reaction had subsided. It was then left for 2.5 hr. and poured on crushed ice and sodium hydrogen carbonate. When all the acid present had been neutralised the ketol trifluoroacetate was separated and poured into concentrated sodium carbonate solution with which it was shaken for 20 min. The organic layer, which now consisted almost entirely of *cyclohexenyl propyl ketone* was extracted with ether and dried (MgSO_4). Evaporation of the ether and a trace of unchanged *cyclohexene* left a sweet-smelling liquid, which was distilled. These fractions were taken : (i) b. p. 67—77°/5 mm., n_D^{21} 1.4505, 2.41 g.; (ii) b. p. 77—81°/5 mm., n_D^{21} 1.4680, d_4^{20} 0.95, 6.06 g.; (iii) b. p. 81—97°/5 mm., 1.05 g. Fraction (i) consisted of *cyclohexenyl propyl ketone* contaminated with a fluorine-containing compound, probably *cyclohexyl trifluoroacetate* [this ester, b. p. 151.5°, n_D^{25} 1.3801, is formed by the direct addition of trifluoroacetic acid to *cyclohexene* (Zimmer and Henne, unpublished work)]. The whole fraction was treated with gaseous ammonia and then washed with water (ammonia would convert *cyclohexyl trifluoroacetate* into trifluoroacetamide and *cyclohexanol*, both water-soluble), and the upper layer was separated and dried (n_D^{23} 1.4685, 1.7 g.). Fraction (ii) consisted of almost pure *cyclohexenyl propyl ketone*, and fraction (iii) was not investigated in detail, but contained traces of fluorine and probably consisted of 2-butyl*cyclohexyl trifluoroacetate* contaminated with polymeric material. The yield of *cyclohexenyl propyl ketone* was 7.8 g. (51%). Its semicarbazone had m. p. 172.5°. Darzens and Rost (*Compt. rend.*, 1910, 151, 758) reported *cyclohexenyl propyl ketone*, b. p. 113—114°/7 mm., and for the semicarbazone, m. p. 171°.

Oct-3-en-2-one.—Hex-1-ene (12.5 c.c.) was added to a solution of acetic acid (5.6 c.c.) in trifluoroacetic anhydride (14.0 c.c.), kept at room temperature (26°) for 20 min., warmed at 40°

for 1.5 hr., and finally left at room temperature (26—27°) for 14 hr. At the end of this time the mixture was poured into aqueous sodium carbonate solution and was then stirred with excess of sodium carbonate for 1 hr. The alkaline mixture was extracted with ether and dried (MgSO_4), and the ether evaporated off. The residue was distilled and the temperature rose steadily; four fractions were taken. Fraction (i), b. p. 35—45°/5 mm., n_D^{25} 1.4366, contained no fluorine and gave a semicarbazone, m. p. 110—111°. Fraction (ii), b. p. 45—50°/5 mm., n_D^{25} 1.4332, contained a trace of fluorine and gave a semicarbazone, m. p. 110—112°. Fraction (iii), b. p. 50—55°/5 mm., n_D^{25} 1.3965, contained fluorine, and gave a semicarbazone, m. p. 109—111°. Fraction (iv), b. p. 60—95°/5 mm., n_D^{25} 1.4270, contained a trace of fluorine and gave no semicarbazone. Fractions (i) and (ii) consisted of oct-3-en-2-one, fraction (ii) containing just a trace of the ketol trifluoroacetate. Fraction (iii) also consisted principally of oct-3-en-2-one with an appreciable proportion of the ketol trifluoroacetate. The proportion of trifluoroacetate, estimated by treating a weighed portion of fraction (iii) with standard alkali, was found to be 41%. Fraction (iv) consisted of polymeric material which was not investigated and there was a residue of polymer (0.96 g.) which was not distilled. Total yields were: oct-3-en-2-one 2.69 g. (22%) and 1-acetylhexyl trifluoroacetate 0.33 g. (1.4%). Oct-3-en-2-one semicarbazone had m. p. 111—112° (Found: C, 59.3; H, 9.3. $\text{C}_9\text{H}_{17}\text{ON}_3$ requires C, 59.0; H, 9.3%).

Octane-2 : 4-dione.—(a) Hex-1-yne (11.4 c.c.) was added to acetic acid (5.7 c.c.) and trifluoroacetic anhydride (14.5 c.c.). A red-brown colour developed immediately, which darkened slowly while the mixture was left at room temperature (27°) for 18 hr. Methyl alcohol (25 c.c.) was then added and the mixture was refluxed for 90 min. The first product collected on distillation was methyl trifluoroacetate, b. p. 41°, n_D^{25} 1.3057; this was followed by mixtures of methyl acetate and unchanged methanol boiling between 60° and 65°. No further material came over at atmospheric pressure and the remaining products were distilled under reduced pressure. Fraction I, b. p. 45—50°/3.5—4.0 mm. (mainly at 48°/3.5 mm.), n_D^{25} 1.4484 (2.41 g.), was pure octane-2 : 4-dione. Fraction II, b. p. 50—75°, n_D^{25} 1.4471 (0.57 g.), was dione contaminated with polymeric material. There was a residue of non-volatile material (3.9 g.). The total yield of octane-2 : 4-dione was 2.84 g. (20.2%). A portion of fraction II treated with cupric acetate gave a 75% yield of the dione copper chelate complex, m. p. 143.5—144.5° (Found: C, 55.0; H, 7.9. Calc. for $\text{C}_{16}\text{H}_{28}\text{O}_4\text{Cu}$: C, 55.2; H, 8.1%). Morgan and Holmes (*J.*, 1924, 125, 761) reported the copper derivative, m. p. 143°. Semicarbazide gave a product, m. p. 89°; Hurd and Kelso (*J. Amer. Chem. Soc.*, 1940, 62, 2186) reported 5-butyl-3-methylpyrazole-1-carboxamide, m. p. 89—90°.

(b) Acetic acid (5.7 c.c.) was added to hex-1-yne (11.4 c.c.) and trifluoroacetic anhydride (14.0 c.c.) and left for 2.5 hr., before it was poured into ice-water. The products were separated by extraction with ether, and the extract was washed thoroughly with sodium hydrogen carbonate solution and distilled water. The ethereal solution was dried (MgSO_4) and evaporated and the main product distilled. A single high-boiling fraction (b. p. 58—60/4—5 mm., n_D^{25} 1.4287, containing fluorine) was obtained. This was treated with methanol and after 90 min. refluxing the low-boiling products were distilled off and collected. This distillate which consisted of methyl trifluoroacetate and unchanged methanol was treated with gaseous ammonia, and the excess of methanol evaporated, to leave trifluoroacetamide, m. p. 71°. The residue was treated with cupric acetate solution and yielded octane-2 : 4-dione copper chelate complex, m. p. 143.4°.

3-Oxo-octanoylbenzene.—Trifluoroacetic anhydride (18.4 c.c.) was added to a mixture of hex-1-yne (14.9 c.c.) and benzoic acid (16.0 g.). The acid dissolved slowly and the solution developed a pink colour which deepened rapidly. After 17 hr. at room temperature, methyl alcohol (30 c.c.) was added and the solution heated under reflux for 2 hr. Methyl trifluoroacetate and unchanged methyl alcohol were distilled off at atmospheric pressure, the remaining volatile components being collected *in vacuo*, leaving a dark residue (6.3 g.). Distillation was hampered by unchanged benzoic acid which crystallised throughout the distillation apparatus so that no discrete fractions could be taken. The whole distillate was treated with sodium hydrogen carbonate solution, followed by cupric acetate. The copper derivative of the diketone was isolated by chloroform-extraction, the yield after a single recrystallisation being 4.01 g. (17%). Two further recrystallisations were necessary to obtain a constant m. p. of 124—125°. This diketone was described by Beyer and Claisen (*Ber.*, 1887, 20, 2178) as a liquid, b. p. 183—184°/30 mm., forming a copper derivative (no m. p. given).