CXXIII.—*The Intermolecular Condensation of Styryl Ketones. Part III. Further Examples of the Ready Formation of Bis-(Styryl Ketones).*

By Isidor Morris Heilbron and Francis Irving.

In a previous communication (Heilbron and Irving, J., 1928, 2323), an account was given of the formation of bis-(styryl nonyl ketones). We have now investigated the interaction of benzaldehyde with methyl *n*-propyl ketone and higher homologues up to methyl *n*-octyl ketone and find that in all cases both the simple styryl ketone and its dimeride can be obtained. In the branched-chain series, only four ketones have been examined and of these methyl *iso*butyl and methyl *iso*hexyl ketones yield dimerides, but methyl *iso*propyl ketone and pinacolin fail to do so. Some of the dimerides have been obtained by previous workers without, however, their identity having been recognised. For instance, *bis-(styryl* n-*propyl ketone)* was actually prepared by Vorländer (*Ber.*, 1897, **30**, 2267), but was regarded by him as a complex triketone; other similar examples are dealt with in the experimental portion.

The styryl ketones are readily distinguished from their bis-forms by the very wide difference in melting point which exists between them and also by the fact that, whereas the former separate in well-defined crystals, the dimerides usually form masses of felted needles (cotton-wool appearance). These points are well exemplified in the case of methyl *n*-hexyl ketone, where the simple styryl derivative crystallises in definite plates, m. p. 32—33°, and the *dimeride* forms clusters of hair-like needles, m. p. 152°. Similarly, 4-*methoxystyryl hexyl ketone* has m. p. 55°, whereas the dimeride melts at 145—146°.

Among the straight-chain dimerides, a certain regularity in melting point is apparent, increase in the length of the carbon chain by a methylene group causing a lowering of m. p. of approximately 13°. In the cases so far examined, the branched chain dimerides have higher m. p.'s than the corresponding straight-chain isomerides.

In connexion with the above melting points an investigation by Rupe and Wild (*Annalen*, 1916, **414**, 111) comes under review. These authors prepared the active and the inactive forms of amylacetone (ε-methylheptan-β-one, $CH_3{\cdot}CO{\cdot}CH_2{\cdot}CH_2{\cdot}CHMe{\cdot}CH_2{\cdot}CH_3$) and condensed them with benzaldehyde and with anisaldehyde. The styryl γ-methylamyl ketones were obtained as colourless, felted needles, m. p. 139° (active) and 173° (inactive). On the other hand, 4-methoxystyryl γ-methylamyl ketone (active) is described as forming large, pearly scales, m. p. 55°. There can be little doubt from these descriptions that, whereas the two former compounds are actually dimerides and thus wrongly designated, the latter is correctly named. In support of this contention it is of interest to note that Rupe and Wild unexpectedly obtained a higher rotation value for the compound of m. p. 139° ($\alpha_D^{20^\circ}$ +10·77°) than for that of m. p. 55° ($\alpha_D^{20^\circ}$ +8·62°), and mention that the anomaly " bedarf noch weiterer Untersuchung "; in view, however, of the facts now pointed out, the explanation is self-evident.

As regards the formation of the bis-compounds, we have found that (*a*) the higher members of the series are the more easily produced and (*b*) a substituted aldehyde gives rise to a dimeride less readily than benzaldehyde itself. Further, as already mentioned, dimerides are only formed from branched-chain ketones when at least one methylene group separates the branch radical from the carbonyl group—a fact which points to steric hindrance, especially on the basis of the dimerides being *cyclo*butane derivatives (compare Heilbron and Irving, *loc. cit.*). In no case has the formation of a *cyclo*hexenone derivative, such as was obtained from 3 : 4-dimethoxystyryl methyl ketone (Dickinson, Heilbron, and Irving, J., 1927, 1888), been observed, and it may be concluded that this only occurs when the styryl ketone has a terminal methyl radical.

The solvent appears to be one of the main factors determining the formation of the mono- or the bis-form during the condensation. In aqueous alcohol (60—70%), the styryl ketone itself is formed, probably owing to its ready separation and consequent removal from the action of the alkali; but when absolute alcohol is employed, the dimeride is produced even under the same conditions of alkali concentration.

The dimerides of the higher members of the series may prove useful in the identification of the ketones, since they are very easily prepared and have high melting points.

EXPERIMENTAL.

Styryl *n*-propyl ketone has been prepared by Harries and Bromberger (*Ber.*, 1902, **35**, 3088), and is a liquid at the ordinary temperature.

Bis-(Styryl n*-Propyl Ketone).*—A solution of benzaldehyde (21 g.) and methyl *n*-propyl ketone (17 g.) in absolute alcohol (100 c.c.) was treated with 10% sodium hydroxide solution (15 c.c.) and kept at room temperature for 2 days; crystals then began to separate. After 4 days, these were recrystallised from alcohol–ethyl acetate, small, colourless, glistening needles being obtained, m. p. 194—195° (Vorländer, *loc. cit.*, gives 197°). The compound dissolved in concentrated sulphuric acid to a yellow solution, and failed to decolorise a solution of bromine in chloroform [Found : C, 82·9, 82·8; H, 8·2, 8·2; *M* (Menzies), 350, 347. $C_{24}H_{28}O_2$ requires C, 82·8; H, 8·1%; *M*, 348].

Styryl *n*-butyl ketone (m. p. 38—39°) has been prepared by Auwers and Voss (*Ber.*, 1909, **42**, 4421) by condensing benzaldehyde with methyl *n*-butyl ketone in presence of alkali and has also been obtained by an indirect method by Mayer (*Bull. Soc. chim.*, 1905, **33**, 397).

Bis-(Styryl n*-Butyl Ketone).*—A solution of methyl *n*-butyl ketone (12 g.) and benzaldehyde (12·5 g.) in absolute alcohol (90 c.c.) was treated with 30% sodium hydroxide solution (8 c.c.) at room temperature, crystals beginning to separate after 12 hours. The product, after 4 days' standing, crystallised from ethyl acetate in fine, colourless needles, m. p. 175—176° (Found : C, 83·0; H, 8·7; *M*, 383. $C_{26}H_{32}O_2$ requires C, 83·0; H, 8·7%; *M*, 376).

Bis-(Styryl iso*Butyl Ketone).*—Gheorghiu and Arwentiew (*J. pr. Chem.*, 1928, **118**, 295), on condensing benzaldehyde with methyl *iso*butyl ketone in presence of alkali, obtained the liquid styryl *iso*butyl ketone, together with a small amount of a product, m. p. 197°, which they regarded as an isomeride or a polymeride. We find this compound to be dimeric styryl *iso*butyl ketone and have obtained it both by the method of these authors and also by the following processes: (1) A solution of benzaldehyde (25 g.) and methyl *iso*butyl ketone (24 g.) in absolute alcohol (170 c.c.) was treated with 25% sodium hydroxide solution (15 c.c.) and kept at room temperature for 7 days. The product, after being washed with alcohol, crystallised from alcohol–ethyl acetate in colourless needles, m. p. 202° (yield, 6·5 g.). (2) A solution of styryl *iso*butyl ketone (5 g.) in absolute alcohol (40 c.c.) was treated with 25% sodium hydroxide solution (10 c.c.) and kept at room temperature for 7 days, crystals of the dimeride slowly separating (yield, 0·8 g.). The compound gives a slightly yellow solution in concentrated sulphuric acid and fails to decolorise a solution of bromine in chloroform (Found: C, 83·1; H, 8·7; *M*, 379. $C_{26}H_{32}O_2$ requires C, 83·0; H, 8·5%; *M*, 376).

*Bis-(4-*iso*Propylstyryl* iso*Butyl Ketone).*—A solution of cuminal (4·5 g.) and methyl *iso*butyl ketone (3 g.) in alcohol (20 c.c.) was first treated with 15% sodium hydroxide solution (2 c.c.) and then, after 1 day, with 30% sodium hydroxide solution (1 c.c.). The whole was left for 8 days, and the product then crystallised from alcohol–ethyl acetate. The same product was obtained by allowing the same quantities of aldehyde and ketone, dissolved in alcoholic potassium hydroxide (22 c.c. of 4%), to remain at room temperature for 4 weeks. *Bis-(4-*iso*propyl* iso*butyl ketone)* forms colourless, glistening, hair-like needles, m. p. 192—194° (Found: C, 83·2; H, 9·6; *M*, 473. $C_{32}H_{44}O_2$ requires C, 83·5; H, 9·6%; *M*, 460).

Unsuccessful attempts were made to obtain dimerides by the condensation of methyl *iso*butyl ketone with piperonal, veratraldehyde, and *p*-chlorobenzaldehyde.

Styryl *n*-hexyl ketone (m. p. 34°) has been described by Mayer (*loc. cit.*; *Bull. Soc. chim.*, 1916, **19**, 431), who obtained it by allowing methyl *n*-hexyl ketone to react with benzylideneaniline and decomposing the product with sulphuric or acetic acid. We have now prepared the ketone by direct alkali condensation in the following manner: Benzaldehyde (2 g.) and methyl *n*-hexyl ketone (2·2 g.) were dissolved in 60 c.c. of 70% alcohol containing 0·3 g. of potassium hydroxide. After standing at room temperature for 2 days, the pale yellow solution was slightly diluted; a pale yellow oil, which solidified on freezing, then separated. Recrystallisation from methyl alcohol in a freezing mixture gave faintly yellow plates, m. p. 32—33°.

Bis-(Styryl n-*Hexyl Ketone).*—A solution of benzaldehyde (2 g.) and methyl *n*-hexyl ketone (2·2 g.) in absolute alcohol (10 c.c.) was mixed with sodium hydroxide (1 c.c. of 30%) and kept over-night at room temperature. The separated product was washed with alcohol and repeatedly crystallised from alcohol–ethyl acetate. The *dimeride* separated in fine matted needles, m. p. 152° (Found: C, 83·3; H, 9·5; *M*, 442. $C_{30}H_{40}O_2$ requires C, 83·3; H, 9·3%; *M*, 432).

4-*Methoxystyryl* n-*Hexyl Ketone.*—A solution of anisaldehyde (2 g.) and methyl *n*-hexyl ketone (2 g.) in alcohol (12 c.c.) was treated with sodium hydroxide (8 c.c. of 1%) and kept at room temperature for a few hours; a yellow oil, which solidified on cooling in the ice-chest, then separated. The pure *ketone* separated from methyl alcohol in colourless plates (pearly scales from aqueous methyl alcohol), m. p. 55° (Found: C, 77·9; H, 9·1. $C_{16}H_{22}O_2$ requires C, 78·0; H, 8·9%).

Bis-(4-Methoxystyryl n-*Hexyl Ketone).*—The same quantities of anisaldehyde and methyl *n*-hexyl ketone as were used in the previous experiment were dissolved in 3% alcoholic potassium hydroxide, and the solution heated under reflux for 4 hours. The product crystallised from alcohol in fine, colourless, felted needles, m. p. 145—146°. Attempts to form this *dimeride* by working at the ordinary temperature were unsuccessful (Found: C, 77·9; H, 9·0; *M*, 512. $C_{32}H_{44}O_4$ requires C, 78·0; H, 8·9%; *M*, 492).

Bis-(Styryl iso*Hexyl Ketone).*—A solution of benzaldehyde (5 g.) and methyl *iso*hexyl ketone (5·5 g.) in absolute alcohol (25 c.c.) was kept for 12 hours at room temperature in presence of sodium hydroxide (2·5 c.c. of 30%). The separated product crystallised from alcohol–ethyl acetate in fine, colourless, matted needles, m. p. 177° (Found: C, 83·4; H, 9·5; *M*, 436. $C_{30}H_{40}O_2$ requires C, 83·3; H, 9·3%; *M*, 432).

Styryl *n*-heptyl ketone (m. p. 52°) has been prepared by Mayer (*loc. cit.*) by the indirect method to which reference has already been made. It can, however, be obtained with ease by direct alkali condensation in the following manner: Benzaldehyde (2 g.) and methyl *n*-heptyl ketone (2·7 g.) were dissolved in 75% alcohol (60 c.c.) containing 0·3 g. of potassium hydroxide. The product commenced to separate in a few hours, and after 2 days colourless leaflets of the pure ketone (m. p. 51—52°) were obtained (yield, 3 g.); the filtrate slowly deposited a small quantity of the dimeride described below.

Bis-(Styryl n-*Heptyl Ketone).*—A solution of benzaldehyde (4 g.)

and methyl *n*-heptyl ketone (5·6 g.) in absolute alcohol (20 c.c.) was treated with 30% sodium hydroxide solution (0·8 c.c.) and kept at room temperature for 5 days. After repeated crystallisation from absolute alcohol, the *dimeride* was obtained in fine, matted, colourless needles, m. p. 144° (Found : C, 83·5; H, 9·5; *M*, 466. $C_{32}H_{44}O_2$ requires C, 83·5; H, 9·6%; *M*, 460).

Styryl n-*Octyl Ketone*.—Benzaldehyde (2 g.) and methyl *n*-octyl ketone (3 g.) were dissolved in alcohol (60 c.c. of 75%) containing 0·2 g. of potassium hydroxide, and the solution kept at room temperature for 2 days. The product was recrystallised from methyl alcohol in a freezing mixture, the pure *ketone* separating in pale yellow leaflets, m. p. 38—39° (Found : C, 83·8; H, 10·0. $C_{17}H_{24}O$ requires C, 83·6; H, 9·8%).

Bis-(Styryl n-*Octyl Ketone)*.—A solution of benzaldehyde (4·1 g.) and methyl octyl ketone (6 g.) in absolute alcohol (20 c.c.) was treated with sodium hydroxide solution (0·2 c.c. of 30%), clusters of fine needles gradually separating. After 4 days the product was collected and recrystallised from absolute alcohol, a felted mass of very fine, colourless needles being obtained, m. p. 131·5° (yield, 0·9 g. of pure substance) (Found : C, 83·7; H, 9·7; *M*, 487. $C_{34}H_{48}O_2$ requires C, 83·6; H, 9·8%; *M*, 488).

THE UNIVERSITY, LIVERPOOL.

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