# 122. *Molecular Rearrangements. Part V.* A Case of a Thermal Reversible α-Diketone–γ-Lactone Rearrangement. Some Experiments with Vulpinic Acid and Related Compounds.*

By Alexander Schönberg and Aly Sina.

In the molten state oxalyl dibenzyl ketone (I) and its isomer (II) form an equilibrium mixture. The naturally occurring vulpinic acid (VI) was degraded *via* pulvinic acid (V) into (II) by using a copper chromite catalyst. The action of *o*-phenylenediamine on vulpinic acid and related substances was investigated; it led to the formation of a condensation product which on hydrolysis with alcoholic potassium hydroxide yielded 2-benzylbenziminazole (compare scheme A).

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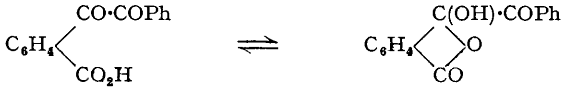
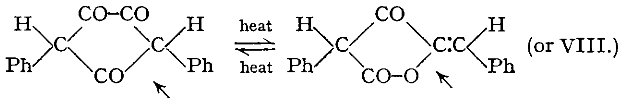
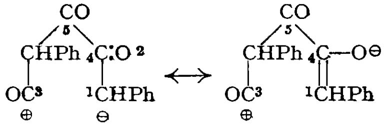
* Cf. Schönberg and co-workers, *Ber.*, 1930, **63**, 178; *Annalen*, 1930, **483**, 107; *Ber.*, 1931, **64**, 1390; 1933, **66**, 250.

(A) REVERSIBLE α-diketone–γ-lactone rearrangements are already known as in the case of benzil-*o*-carboxylic acid (Hantzsch and Schwiete, *Ber.*, 1916, **49**, 220), but this is an example of simple ring-chain tautomerism:



Claisen and Ewan (*Annalen*, 1894, **294**, 276) found that, at about 228°, oxalyl dibenzyl ketone (1 : 3-diphenyl-*cyclo*pentan-2 : 4 : 5-trione) is rapidly converted by heat into its isomer (yield 75%), which, they stated, could not be reconverted by heat into the original ketone. According to our observations, this thermal rearrangement involves equilibrium between the homocyclic ring and a γ-lactone, (I) ⇌ (II). When (II) is heated above 270° the resulting equilibrium mixture of (I) and (II) has its equilibrium disturbed by the removal of (I) by sublimation. It is thus possible to obtain (I) from (II) in excellent yield.


(I.) (II.)

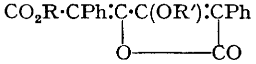

(III.) (IV.)

To explain this thermal change the following theory is advanced: Ionic fission of the bonds marked with an arrow in (I) and (II) affords a " zwitterion " which would be a resonance hybrid of structures (III) and (IV); rotation about the $C^5$–$C^4$ bond can then bring into close proximity either atoms $C^1$ and $C^3$ (to yield I) or $O^2$ and $C^3$ (to yield II).

(B) One of the most important derivatives of the so-called " *iso*oxalyl dibenzyl ketone " (II) is pulvinic acid (V), the methyl ether of which, vulpinic acid (VI), occurs in nature. The following experiments have been made with this acid and related compounds.

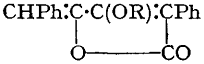
(a) *Degradation of pulvinic acid* (V) *to* isooxalyl *dibenzyl ketone.* Hitherto, this degradation had not been achieved, Claisen and Ewan (*loc. cit.*, p. 295) having failed to effect it, but we have now done so by heating pulvinic acid with copper chromite and quinoline, thus giving additional proof of the relationship between the acid and the ketone.

(b) *Action of diazomethane on pulvinic acid and* isooxalyl *dibenzyl ketone.* In both cases a vigorous reaction took place, the methyl ethers of vulpinic acid and *iso*oxalyl dibenzyl ketone, (VII) and (IX) respectively, being obtained.



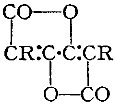
$$\mathrm{CO_2R{\cdot}CPh{:}\underset{|\;\;\;\;O\text{———}}{C}{\cdot}C(OR'){:}\underset{CO}{CPh}}$$

(V), R = R′ = H (pulvinic acid).
(VI), R = Me; R′ = H (vulpinic acid).
(VII), R = R′ = Me.



$$\mathrm{CHPh{:}\underset{O\text{———}}{C}{\cdot}C(OR){:}\underset{CO}{CPh}}$$

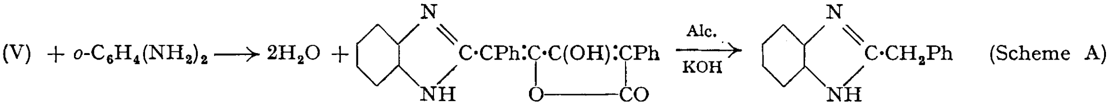
(VIII), R = H.
(IX), R = Me.



$$\mathrm{\overset{CO\text{—}O}{CR{:}C{\cdot}C{:}CR}\atop O\text{—}CO}$$

(X*a*), R = Ph.
(X*b*), R = *p*-$C_6H_4OMe$.

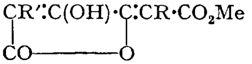
(c) *Action of* o-*phenylenediamine on pulvinic acid, vulpinic acid, pulvinic acid dilactone* (X*a*) *and* pp′-*dimethoxy-pulvinic acid dilactone* (X*b*). This action leads in the first three cases to the benziminazole *derivative* (XI), an orange substance soluble in sodium hydroxide. Similarly, from *o*-phenylenediamine and *pp*′-dimethoxy-pulvinic acid dilactone (X*b*), the pp′-*dimethoxy*-derivative of (XI) was obtained. By the action of diazomethane or methyl sulphate, (XI) is converted into a yellow O-*methyl ether*.



(XI.) (XII.)

When (XI) was treated with alcoholic potassium hydroxide, a colourless product was obtained which proved to be 2-benzylbenziminazole (XII), and this, when treated with selenium (precipitated) in the presence of oxygen, yielded benzoic acid.

This new degradation method of vulpinic acid and related compounds (compare scheme A) should be of value in ascertaining the constitution of asymmetrically substituted derivatives of vulpinic acid. For example,



$$\mathrm{\underset{CO\text{————}}{CR'}{:}C(OH){\cdot}\underset{O}{C}{:}CR{\cdot}CO_2Me}$$

(XIII*a*), R = Ph; R′ = *p*-$C_6H_4{\cdot}OMe$.
(XIII*b*), R = *p*-$C_6H_4{\cdot}OMe$; R′ = Ph.

the synthesis of the naturally occurring pinastrinic acid could lead to (XIII*a*) or (XIII*b*). The benziminazole derivative of pinastrinic acid, prepared according to scheme A, should yield, on alkaline hydrolysis, 2-benzylbenziminazole (XII) if the proposed formula (XIII*a*) for pinastrinic acid is correct (cf. Asano and Kameda, *Ber.*, 1934, **67**, 1522); otherwise 2-(*p*-methoxybenzyl)benziminazole would be obtained.

## EXPERIMENTAL.

(A) *Transformation of* iso*Oxalyl Dibenzyl Ketone* (II) *into Oxalyl Dibenzyl Ketone* (I).—0·5 G. of (II) was heated under 40 mm., or in a stream of dry carbon dioxide, at 271° (bath temp.). [It is important that the sublimate of (I) which is formed during this process should be protected from heat, otherwise it melts and is reconverted into (II); therefore it is advisable to work with a metal-bath the surface of which is covered with asbestos.] Nearly the whole sublimed into the cooler parts of the reaction vessel, and the sublimate proved to be oxalyl dibenzyl ketone, m. p. 192° not depressed by admixture with an authentic sample (Found: C, 77·1; H, 4·7. Calc. for $C_{17}H_{12}O_3$: C, 77·3; H, 4·6%).

The quinoxaline derivative, prepared from the sublimate and *o*-phenylenediamine, had m. p. 255° not depressed by admixture with an authentic sample (cf. Chakravarti, *Centr.*, 1926, I, 120). We found that it is unaffected by an ethereal solution of diazomethane, showing that it has no tendency to react in the enolic form.

*Detection of oxalyl dibenzyl ketone in the melt of* iso*oxalyl dibenzyl ketone.* The *iso*-ketone (0·5 g.) was put in a sealed tube and completely immersed in a boiling ethyl cinnamate bath, in order to avoid sublimation of oxalyl dibenzyl ketone on the cooler parts of the vessel. After the substance had melted, it was left in the boiling bath for a further 5 minutes and then taken out.

(i) Colour reaction. An alcoholic solution of the melt gives with alcoholic ferric chloride a brownish-green coloration characteristic of oxalyl dibenzyl ketone; *iso*oxalyl dibenzyl ketone gives no colour with the same reagent (cf. Claisen and Ewan, *loc. cit.*, p. 252).

(ii) Isolation. The cooled melt was extracted with boiling benzene in which oxalyl dibenzyl ketone is more soluble than the *iso*-ketone. From this extract, after several crystallisations from benzene, a small amount of oxalyl dibenzyl ketone was obtained (identified by m. p., mixed m. p. with an authentic sample, and the above colour reaction).

*Action of heat on oxalyl dibenzyl ketone in a closed vessel.* The reaction was carried out as described above for the *iso*-ketone. The substance first melted, then resolidified, and then remelted when it was heated for a further 5 minutes. The cooled crystalline melt had m. p. 248° and consisted principally of the *iso*-ketone (m. p. 253°). To prove the presence of oxalyl dibenzyl ketone in the melt, it was treated with hot benzene, as described above, and this ketone was obtained (identified by mixed m. p. and ferric chloride reaction).

Even after prolonged heating (one hour) in a boiling ethyl cinnamate bath, the presence of oxalyl dibenzyl ketone could be proved by the ferric chloride reaction, and complete conversion of (I) into (II) could not be effected. On more prolonged heating, the *iso*-ketone resinified.

*Oxidation of* iso*Oxalyl Dibenzyl Ketone.*—This ketone (15 g.) was dissolved in 200 c.c. of 3% aqueous sodium carbonate, and the mixture diluted to 400 c.c. and cooled to 0°. Then, with continuous stirring, an ice-cold solution of potassium permanganate (18 g. in 200 c.c. of water) was added gradually, the mixture being kept at 0°. After 2 hours the mixture was filtered, and the residue washed with ether. The filtrate was extracted with ether repeatedly, the ethereal extracts combined, and the ether driven off, leaving an oily residue (6 g.). 2 G. of this residue were treated with an aqueous solution of phenylhydrazine acetate in the usual manner, and 1·3 g. of crystalline benzaldehyde phenylhydrazone were obtained (cf. Claisen and Ewan, *loc. cit.*, p. 282).

(B) *Condensation of Vulpinic Acid* (VI) *with* o-*Phenylenediamine Hydrochloride.*—Vulpinic acid (Volhard, *Annalen*, 1894, **282**, 13) (0·5 g.) and *o*-phenylenediamine hydrochloride (0·35) g. were mixed with *N*-dimethylaniline (15 c.c.), and the whole boiled under reflux for 2 hours. After cooling, the solution was poured into dilute hydrochloric acid, and the mixture well stirred. The separated solid was washed with dilute hydrochloric acid and then with distilled water. The dry reaction product crystallised from ethyl acetate as orange needles, m. p. 312° (Found: C, 75·5; H, 4·4; N, 7·7. $C_{24}H_{16}O_3N_2$ requires C, 75·8; H, 4·2; N, 7·4%). *βγ-Dihydroxy-αδ-diphenyl-δ-2-benziminazolyl-*$\Delta^{\alpha\gamma}$*-pentadienoic acid lactone* (XI) is soluble in dilute aqueous potassium hydroxide, giving a yellow solution from which the original substance is precipitated on acidification with dilute hydrochloric acid. It is difficultly soluble in benzene and alcohol, but soluble in hot ethyl acetate and glacial acetic acid.

*Condensation of Pulvinic Acid* (V), *Pulvinic Acid Dilactone* (X*a*), *and* pp′-*Dimethoxypulvinic Acid Dilactone with* o-*Phenylenediamine.*—Pulvinic acid (Volhard, *loc. cit.*, p. 14) or its dilactone, similarly treated, afford the compound (XI), m. p. 314° not depressed by admixture with the specimen obtained above [Found, from (V): C, 75·5; H, 4·3; N, 7·4. Found, from (X*a*): C, 75·4; H, 4·3; N, 7·7%].

*pp*′-Dimethoxypulvinic acid dilactone (Kögl, *Annalen*, 1928, **465**, 254), similarly treated, afforded the pp′-*dimethoxy*-derivative of (XI), deep reddish-orange crystals, m. p. 334° after crystallisation from ethyl acetate (Found: C, 70·7; H, 4·5; N, 6·1. $C_{26}H_{20}O_5N_2$ requires C, 70·9; H, 4·6; N, 6·4%), difficultly soluble in alcohol, but soluble in hot ethyl acetate and hot glacial acetic acid.

*Hydrolysis of* (XI) *with alcoholic potassium hydroxide.* 1 G. of (XI) was refluxed with 20 c.c. of alcoholic potash (4 g. of potassium hydroxide in 40 c.c. of 95% alcohol) for 3 hours. Colourless crystals of potassium oxalate separated during the hydrolysis. The mother-liquor, after filtration, was acidified with dilute hydrochloric acid and concentrated to a small volume; an oil separated, which solidified on standing in ice. This was collected, washed with distilled water until free from inorganic salts, and crystallised twice from dilute alcohol (charcoal). On dissolving these crystals in the minimum of distilled water and making the solution alkaline with aqueous potassium hydroxide, a white milky precipitate was formed which soon set to colourless needles; recrystallised from dilute alcohol, these had m. p. 189° not depressed when mixed with an authentic sample of 2-benzylbenziminazole (Walther and Pulawski, *J. pr. Chem.*, 1899, **59**, 253) (Found: C, 80·8; H, 5·8; N, 13·4. Calc. for $C_{14}H_{12}N_2$: C, 80·8; H, 5·8; N, 13·4%).

*Oxidation of* 2-*Benzylbenziminazole with Oxygen in Presence of Selenium.*—2-Benzylbenziminazole (0·4 g.) was intimately mixed with precipitated selenium (Kahlbaum) (8 g.), and heated in the bulb of a long-necked pyrolysis flask in a bath the temperature of which was gradually raised to 290°, a continuous stream of air being passed through. In the higher parts of the neck, benzoic acid sublimed (mixed m. p.).

*Methylation of* (XI).—(i) 0·5 G. of (XI) was dissolved in excess of dilute potassium hydroxide, and to the alkaline solution methyl sulphate (4 c.c.) was gradually added with shaking after each addition. The precipitate was collected, washed repeatedly with distilled water, then dried at the water-pump and finally crystallised from absolute alcohol. The O-*methyl ether* of (XI) formed yellow plates, m. p. 325°, difficultly soluble in alcohol, benzene, carbon tetrachloride and ethyl acetate, and insoluble in dilute cold sodium hydroxide solution (Found: C, 75·95; H, 4·9; N, 7·1. $C_{25}H_{18}O_3N_2$ requires C, 76·1; H, 4·6; N, 7·1%); no active hydrogen was found.

(ii) 0·5 G. of (XI) was finely pulverised, suspended in ether, treated with an ice-cold ethereal solution of diazomethane, and left on ice overnight; the yellow solid that separated was collected, washed with cold alcohol and then crystallised from hot methyl alcohol. The yellow crystals had m. p. 326° not depressed by admixture with the product obtained as in (i).

Prolonged treatment with excess of an ethereal solution of diazomethane in the cold failed to methylate either 2-benzyl- or 2-phenyl-benziminazole.

*Action of Diazomethane on* iso*Oxalyl Dibenzyl Ketone.*—0·5 G. of the ketone was methylated as above by diazomethane (from 10 g. of nitrosomethylurea); the crystals which separated on concentration of the solution, crystallised from methyl alcohol, formed colourless crystals of iso*oxalyl dibenzyl ketone methyl ether* (IX), m. p. 106° (Found: C, 77·7; H, 5·1. $C_{18}H_{14}O_3$ requires C, 77·7; H, 5·0%); no active hydrogen was found. (Cf. Kögl, *loc. cit.*, p. 256.)

*Action of Diazomethane on Pulvinic Acid* (V).—This acid, similarly treated, gave vulpinic acid methyl ether (VII), m. p. 142—143° after crystallisation from methyl alcohol (cf. Spiegel, *Annalen*, 1883, **216**, 16) (Found: C, 71·5; H, 4·9. Calc. for $C_{20}H_{16}O_5$: C, 71·4; H, 4·8%).

*Decarboxylation of Pulvinic Acid.*—Pulvinic acid (1 g.) was dissolved in freshly distilled dry quinoline (5 c.c.), and the solution heated (with mechanical stirring) in a boiling nitrobenzene bath for 15 minutes, during which copper chromite (*Org. Synth.*, **19**, 31) (0·8 g.) was gradually added in portions of 0·1 g. After cooling, the reaction mixture was poured into dilute hydrochloric acid and stirred for 10 minutes. The solid was filtered off, washed with distilled water, and then extracted repeatedly with boiling dilute potassium carbonate solution to dissolve *iso*oxalyl dibenzyl ketone. The filtered aqueous extract was washed three times with ether in a separating funnel, freed from ether, acidified with dilute hydrochloric acid, and the resulting yellow precipitate was collected, pressed on a porous plate, and crystallised from toluene containing a small amount of glacial acetic acid. Yellow crystals were formed, m. p. 253° not depressed by admixture with an authentic specimen of *iso*oxalyl dibenzyl ketone.

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