TABLE I

Compound[a]	M. p., °C.	Formula	Analyses, % Calcd. C	Calcd. H	Calcd. N	Found C	Found H	Found N
2-N⁴-Benzoyl-S-quinoxaline[b]	259–260	$C_{21}H_{16}O_3N_4S$	62.34	3.99	13.86	62.18	4.04	13.72
2-N⁴-Caproyl-S-quinoxaline[c]	199–200	$C_{20}H_{22}O_3N_4S$	60.28	5.56	14.07	59.98	5.60	13.81
2-N⁴-Succinyl-S-quinoxaline[d]	234–235	$C_{18}H_{16}O_5N_4S$	53.97	4.07	14.00	53.96	4.05	14.30
2-N⁴-Acetyl-S-3-carboethoxyquinoxaline[e]	236–237	$C_{15}H_{16}O_3N_4S$	55.04	4.38	13.53	54.85	4.78	13.55
2-S-3-Carboxyquinoxaline[e]	238–239	$C_{15}H_{12}O_4N_4S$	52.30	3.51	16.28	52.58	3.91	16.46

[a] S = Sulfanilamido. [b] This compound was obtained by the action of benzoyl chloride on the sulfa drug in pyridine, and purified by crystallizing in a mixture of acetone, isopropanol and water. [c] Prepared from caproyl chloride on the sulfa drug in pyridine, and purified in alcohol–water. This compound shows a tendency to melt or soften at 150–152°, but it solidifies at once, then melts at 199–200°. [d] Prepared with succinyl anhydride and the sulfa drug in pyridine at 90° for two hours. The reaction mixture was diluted with water and the product obtained after adding excess of acetic acid. This compound has a free acid group, and dissolves in sodium bicarbonate solutions. [e] Prepared in the manner described for sulfaquinoxaline.

Acknowledgment.—The authors wish to thank Dr. R. T. Major and Dr. J. R. Stevens for their interest and suggestions.

Summary

1. The synthesis of 2-aminoquinoxaline as well as its conversion to 2-sulfanilamidoquinoxaline has been described.

2. Preliminary chemotherapeutic studies indicate that 2-sulfanilamidoquinoxaline is very effective in bacterial infections and that it has the unusual property of being eliminated by animals very slowly so that effective concentrations can be maintained by administering it at comparatively infrequent intervals.

RAHWAY, N. J. RECEIVED JULY 19, 1944

[CONTRIBUTION FROM THE RESEARCH DEPARTMENT, CALCO CHEMICAL DIVISION, AMERICAN CYANAMID COMPANY]

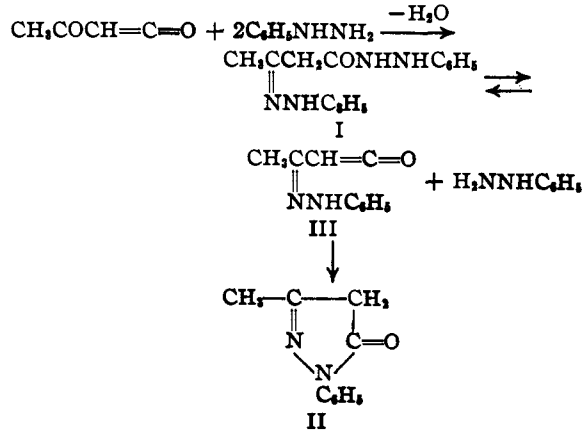
The Reactions of Arylhydrazines with Diketene and the Preparation of 1-Aryl-5-methyl-3-pyrazolones

BY H. Z. LECHER, R. P. PARKER AND R. C. CONN

While investigating some potential uses of diketene, we studied its reaction with arylhydrazines under various conditions. It was known to prepare 1-aryl-3-methyl-5-pyrazolones from these starting materials. We found that the isomeric 1-aryl-5-methyl-3-pyrazolones too may be easily prepared from them. In contrast to the 5-pyrazolones these 3-pyrazolones have not been as extensively investigated. This is probably due to the fact that their preparation has been cumbersome.

In their investigation of diketene Chick and Wilsmore[1] treated it with phenylhydrazine and obtained the phenylhydrazone of acetoacetic phenylhydrazide (I). More recently Johnson[2] treated phenylhydrazine with diketene in different proportions and under different conditions and obtained 1-phenyl-3-methyl-5-pyrazolone (II). He used equal molecular quantities in an inert solvent and worked at temperatures higher than 40°. He stated that an intermediate compound is formed during his process, but did not specify the nature of this compound.

By adding two molecular proportions of phenylhydrazine to one of diketene in benzene solution we obtained I in good yield, if the temperature was not allowed to rise. Above room temperature some II was formed, the quantity increasing as the temperature was raised. Addition of one molecular proportion of diketene to I resulted in the formation of II in a 79% yield.

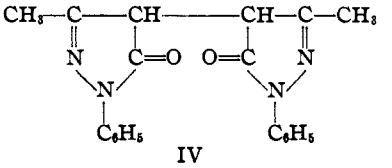


From this it seemed probable that I undergoes a slight thermal dissociation into phenylhydrazine and the phenylhydrazone of diketene (III). This dissociation also seemed to be reversible because I was recovered unchanged after being heated alone in boiling benzene.

Some substantiation of this hypothesis was afforded by the behavior of I on heating above its melting point. Melting was followed by decomposition with liberation of ammonia and forma-

(1) Chick and Wilsmore, *J. Chem. Soc.*, **93**, 948 (1908).
(2) F. Johnson, U. S. Patent 2,017,815.

tion of bis-(1-phenyl-3-methyl-5-pyrazolonyl) (IV) in 72% yield.



IV

Knorr[3] stated that the bis-pyrazolonyl is easily formed by heating II with excess phenylhydrazine. Thus, on heating I above its melting point it is to be expected that both II and phenylhydrazine will be present together and the formation of IV is not surprising.

If our hypothesis of the above stipulated equilibrium is correct, then it is to be expected that anything which will remove phenylhydrazine will complete the dissociation of I and promote the formation of II by ring closure of III. This ring closure is analogous to the formation of II from ethyl acetoacetate and phenylhydrazine which has been shown to proceed with the preliminary formation of the phenylhydrazone of acetoacetic ester.[4,5]

The removal of the phenylhydrazine from this equilibrium may be accomplished by the addition of a second molecule of diketene which, as mentioned above, results in almost complete conversion of I to II. However, the removal of phenylhydrazine was also successfully accomplished by the aid of acids in organic media. Thus, heating I in benzene with slightly more than one mole of glacial acetic acid at 60–66° gave a 75% yield of II; heating I in glacial acetic acid alone gave a 75% yield of crude II which appeared to contain some IV; heating I in benzene in the presence of dry hydrogen chloride gave phenylhydrazine hydrochloride and some impure II. When I was heated with glacial acetic acid in benzene at the boil and part of the benzene was distilled off, then apparently the phenylhydrazine acetate was sufficiently dissociated to permit oxidation of II to IV, and this became the main product of the reaction.

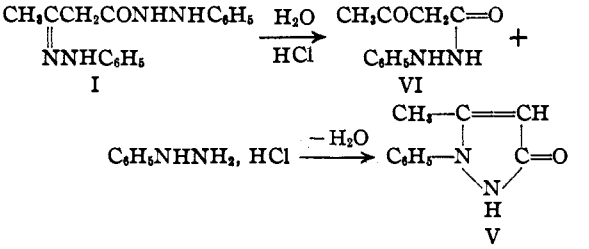
It was also possible to shift the reaction to II by heating I with dilute sodium hydroxide. This combines with II to give the sodium salt of the enol. By heating I with 5 *N* sodium hydroxide a 61.5% yield of fairly pure II was obtained.

The tendency to dissociate seems to vary with different arylhydrazones of acetoacetic arylhydrazides. Thus, the 2′,5′-dichlorophenyl derivative is considerably more stable than the phenyl compound. When 2′,5′-dichlorophenylhydrazine was treated with diketene in boiling benzene according to the conditions of the Johnson[2] patent, only 14.2% of the 5-pyrazolone was obtained and 69.4% of the hydrazone-hydrazide was recovered unchanged. This 1-(2′,5′-dichlorophenyl)-3-methyl-5-pyrazolone has not been adequately described in the literature;[6] we prepared it also from acetoacetic ester and 2,5-dichlorophenylhydrazine.

Very surprising results were obtained when I was heated with strong aqueous acids; in this case, in contrast to the results formerly discussed the isomeric 1-phenyl-5-methyl-3-pyrazolone (V) became the main product of reaction. On heating I with concentrated hydrochloric acid there resulted a 92% yield of pure V. Dilute hydrochloric acid (5 *N*) gave a 71% yield of V and 26% yield of II in addition to some phenylhydrazine. Weaker acids, such as 20% acetic acid, gave only a poor yield of V.

Mixtures of the 3- and 5-pyrazolones were readily separated because of the lower apparent strength of the former, both as an acid and as a base. When a mixture of the two is neutralized, the 3-pyrazolone precipitates first and may be separated by filtration.

The formation of V on heating I with aqueous acids can be explained by hydrolysis of the hydrazone linkage, resulting in the formation of phenylhydrazine and the phenylhydrazide of acetoacetic acid (VI). This latter compound presumably splits out water with the formation of V.



The hydrolysis step finds analogy in the easy splitting of the phenylhydrazone of acetoacetic ester with hydrochloric acid to give acetoacetic ester and phenylhydrazine.[5] The presence of VI as an intermediate in the formation of V from monobenzoyl phenylhydrazine, acetoacetic ester and phosphorus trichloride has been postulated by Michaelis.[7]

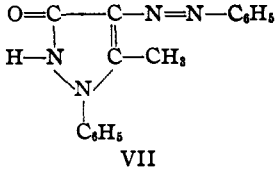
The above reaction constitutes a new and simple synthesis of V. Previously it has been prepared by starting from a β-halogenobutyric acid and phenylhydrazine,[8] and by the condensation of formyl, benzoyl or acetyl phenylhydrazine and acetoacetic ester with PCl_3 or $POCl_3$.[9] This latter method was improved by Mayer[10] and Michaelis.[7] The best results were obtained with the monobenzoyl compound which gave yields up to 65%. There were, however, numerous by-products, including benzoic acid, diben-

(3) Knorr, *Ann.*, **238**, 155 (1887).
(4) Knorr, *ibid.*, **238**, 148 (1887).
(5) Nef, *ibid.*, **266**, 71 (1891).
(6) Various dyes derived from it are described in British Patents 217,594, 230,022, 452,234; French Patent 792,133; Swiss Patent 176,923.
(7) Michaelis, *Ann.*, **338**, 267 (1905).
(8) Lederer, *J. prakt. Chem.*, (2) **45**, 90 (1892).
(9) Stolz, *ibid.*, (2) **55**, 150 (1897).
(10) Mayer, *Ber.*, **36**, 717 (1903).

zoylphenylhydrazine, as well as resinous impurities. This has so far constituted the best method of preparing V.

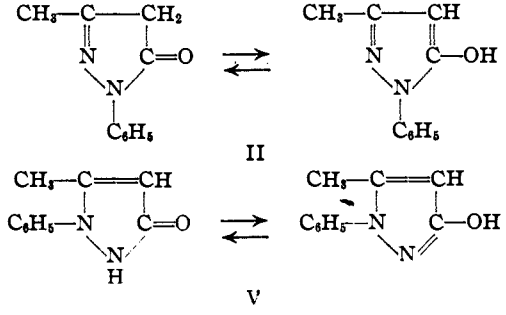
We have extended our synthesis to the preparation of the 2′,5′-dichlorophenyl, 4′-nitrophenyl, and 1′-naphthyl-5-methyl-3-pyrazolones starting with the corresponding hydrazines. In these cases yields of the hydrazone-hydrazides were excellent. The conversion to the corresponding 3-pyrazolones without formation of the 5-isomers was effected smoothly and in excellent yield by boiling with 5 *N* hydrochloric acid in the presence of a little alcohol. These reactions are only briefly summarized in the experimental part because they have already been dealt with elsewhere.[11]

Reactions of 1-aryl-5-methyl-3-pyrazolones have been investigated by Michaelis.[7] In many respects they behave similarly to the corresponding 5-pyrazolones. Of particular interest is the formation of an antipyrine from V, and the reported coupling of V with diazotized aniline to give 1-phenyl-5-methyl-3-pyrazolone-4-azobenzene (VII):



VII

As no further information was available concerning the coupling behavior of V, we investigated this in some detail, particularly since azo dyes derived from the 5-pyrazolone (II) are of great technical importance. It is to be noted that while II and V are both soluble in alkali, their tautomeric forms are entirely different



II

V

II exhibits typical keto–enol tautomerism and is soluble in the enol form. The lone hydrogen attached to the 4-carbon atom of V cannot, however, shift and instead the compound is soluble in the lactim form with hydrogen shifting from the 2-nitrogen. Moreover, the hydrogen attached to the 4-position of V is activated by a double bond attached to C—CH_3 rather than to C—OH. It is to be expected, therefore, that its polarization will not be as great and that the rate of coupling will be slower. In practice, it was found that V was weaker as an acid and less soluble in alkali than II, as would be expected from the difference in their tautomeric forms. Also, it showed noticeably lower coupling power, coupling more slowly and at a higher *p*H than II. Despite these facts, it was found to couple with a variety of diazotized aromatic amines to produce dyes quite similar to those obtained from II.

In these dyes the hydroxyl group of the lactim form of V behaves like a phenolic OH. Thus, the azo dyestuff obtainable by coupling diazotized 1-amino-2-hydroxynaphthalene-4-sulfonic acid may be converted into a stable chromium complex.

In the present paper the original diketene formula of Chick and Wilsmore[1] is used as a matter of convenience.[12] As far as the structure of diketene is concerned, it may be noted that the reaction of diketene with bromine giving the bromide of γ-bromo-acetoacetic acid[13] is not incompatible with the old formula if the tautomerism

$$CH_3COCH{=}C{=}O \rightleftharpoons CH_2{=}C(OH)CH{=}C{=}O$$

is assumed; a 1,4 addition of bromine to the latter compound should give the just mentioned bromide.

Experimental

Preparation of Arylhydrazones of Acetoacetic Arylhydrazides.—These preparations are sufficiently described in our patent[11] and only the following supplemental data are given here: 1. Phenylhydrazone of acetoacetic phenylhydrazide (I) (Example 1 of the patent): crude yield 79.8%; m. p. 148–151° (dec.), after recrystallization from benzene 155° (dec.). 2. 2,5-Dichloro-phenylhydrazone of acetoacetic (2,5-dichloro-phenyl)-hydrazide (Example 4 of the patent): preparation in dry ether preferable, yield 78.5%, m. p. 189–190°.

Anal. Calcd. for $C_{16}H_{14}ON_4Cl_4$: C, 45.74; H, 3.36; N, 13.34. Found: C, 45.1; H, 3.2; N, 14.1.

3. 4-Nitro-phenylhydrazone of acetoacetic-(4-nitrophenyl) hydrazide (Example 5 of the patent): crude yield 95%, very poorly soluble in organic solvents. Purified by slurrying successively with alcohol, benzene, and ether, yellow crystals, m. p. 206° (dec.).

Anal. Calcd. for $C_{16}H_{16}O_5N_6$: C, 51.61; H, 4.33; N, 22.58. Found: C, 51.7; H, 4.2; N, 23.0.

4. 1-Naphthylhydrazone of acetoacetic-(1-naphthyl) hydrazide (Example 6 of the patent): crude yield 86.4%. Difficultly soluble in hot benzene and alcohol, more in hot toluene; its solutions darken rapidly. After slurrying with benzene, alcohol, and ether m. p. 158–159° (dec.), but not pure yet.

Anal. Calcd. for $C_{24}H_{22}ON_4$: C, 75.36; H, 5.75; N, 14.65. Found: C, 72.7; H, 5.6; N, 13.8.

Reaction of I with Diketene.—A slurry of 14.1 g. (0.05 mole) of I was stirred in 200 cc. of benzene in a 1-liter three-necked flask fitted with a mercury-sealed stirrer, dropping funnel and reflux condenser. The benzene was heated to the boil and 4.2 g. (0.05 mole) of diketene dissolved in a little benzene was dropped in. The suspended solid began to go into solution almost at once and after ten minutes of additional stirring solution was practically complete. Droplets of water were noted in the benzene reflux. The reaction mixture was worked up by adding 30 cc. of 5 *N* hydrochloric acid and steam stripping off the benzene. The aqueous solution remaining was stirred with a little Nuchar for a few minutes and filtered. The almost

(11) See our U. S. Patent 2,227,654.

(12) Readers interested in the problem of the structure of diketene will find a review in a recent paper by Rice and Roberts, THIS JOURNAL, **65**, 1677 (1943).

(13) Chick and Wilsmore, *J. Chem. Soc.* **97**, 1978 (1910).

colorless filtrate was neutralized by the addition of sodium bicarbonate and the crystalline product separating filtered. This was 1-phenyl-3-methyl-5-pyrazolone (II), 124–127°; yield, 13.8 g. (79%).

In a blank experiment, the same quantity of I was heated in benzene alone. On cooling and filtering, it was recovered unchanged (m. p. 149.5–151°). The recovery was 93%, a little material going into the filtrate.

Heating of I above the Melting Point.—Five grams of I was placed in a test-tube immersed in an oil-bath and the temperature gradually raised. At a bath temperature of 160°, the solid melted and then began to resolidify. There was considerable foaming and ammonia was evolved. The bath temperature was raised to 190° over twenty minutes and a pasty solid separated. This was cooled and extracted with ether. The white solid remaining was filtered, washed well with ether and dried. The product remained unmelted on heating to 360°. It was easily soluble in dilute alkali and soluble with warming in dilute hydrochloric acid. It showed all the properties of bis-(1-phenyl-3-methyl-5-pyrazolonyl-4) (IV) described by Knorr;[13] yield 2.2 g. (72%).

Anal. Calcd. for $C_{20}H_{18}O_2N_4$: C, 69.35; H, 5.24; N, 16.17. Found: C, 69.1; H, 5.3; N, 16.20.

Further proof of its identity was furnished by conversion to Pyrazole Blue after the procedure of Knorr.[14] A solution of 1.0 g. of the above product in dilute aqueous sodium hydroxide was mixed with an excess of sodium nitrite and the mixture poured into dilute sulfuric acid. A violet-blue precipitate of Pyrazole Blue separated. Precipitated from chloroform with ether, m. p. 235–236°. Knorr gives 230–240°.

Heating of I with Anhydrous Acids.—A mixture of 20.0 g. of I and 100 cc. of glacial acetic acid was stirred and heated. Solution took place at the boil. On cooling, the solution was diluted with water and neutralized with sodium hydroxide. A white precipitate separated, but was redissolved by the addition of excess alkali. The alkaline solution was shaken with ether to remove phenylhydrazine, then neutralized with acetic acid. The product which separated was crude II, m. p. 120–122°; yield 9.3 g. (75%). This appeared to contain some of the high melting bis-pyrazolonyl (IV) as it did not melt entirely clear and further heating above 300° did not change the appearance of the melt. Reprecipitation from alkaline solution with acid raised the melting point to 123°.

A mixture of 7.0 g. (0.025 mole) of I and 1.7 g. (0.028 mole) of glacial acetic acid in 100 cc. of benzene was stirred and gently heated. Solution took place between 60–66°. The clear, yellow solution was immediately cooled and evaporated under an air jet. The slightly oily product was taken up in dilute sodium hydroxide and ether extracted. Reprecipitation with dilute acetic acid gave 3.3 g. (75%) of II, m. p. 124–125°.

A suspension of 5.0 g. of I and 150 cc. of dry benzene was stirred and heated to the boil while passing in a stream of dry hydrogen chloride. The mixture was filtered and the solid (mainly phenylhydrazine hydrochloride) remaining washed with ether. The benzene mother liquor was evaporated under an air jet and the oily residue was dissolved in dilute aqueous sodium hydroxide and, after shaking out with ether, reprecipitated by the addition of dilute acetic acid; yield 1.4 g., m. p. 117–120°.

Heating of I with Aqueous Acids.—With concentrated hydrochloric acid V was almost exclusively formed: 10 g. of I was stirred and heated with 100 cc. of 38% hydrochloric acid. The suspended solid did not go into solution. After short refluxing, water was dropped in until solution was complete (100 cc.). A little Nuchar was added, the solution was clarified and made alkaline by the addition of an excess of dilute aqueous sodium hydroxide which first separated a precipitate and then redissolved it. Dilute acetic acid was added to the neutral point and the separated pure V was filtered, washed, and dried; yield 5.7 g. (92%) (m. p. 163–164°).

Heating with dilute mineral acids and with 20% acetic acid gave mixtures of II and V with the latter being formed in the greater amount. The following experiment is typical and illustrates our method of working up. A mixture of 180 g. of I and 650 cc. of 5 *N* hydrochloric acid was stirred and heated to the boil, solution taking place within a few minutes. A little Nuchar was added and the solution was clarified. After cooling, the filtrate was partially neutralized by the addition of 500 cc. of 5 *N* sodium hydroxide. The heavy precipitate was filtered off, washed with water, and dried; it was crude V, yield 78.8 g. (71%), m. p. 158–161° with preliminary softening; after recrystallization from alcohol, m. p. 166–168° (reported[7] 166°).

Anal. Calcd. for $C_{10}H_{10}N_2O$: C, 68.8; H, 5.74; N, 16.08. Found: C, 68.8; H, 6.10; N, 16.8.

The same sample gave a crystalline hydrochloride precipitating from hot 5 *N* hydrochloric acid; m. p. 129–130° (dec.) (reported[7] 129°). It also formed a crystalline picrate, m. p. 148–149° (reported[7] 141°). The acid mother liquor from the above precipitation (V) was made alkaline by the addition of 150 cc. additional 5 *N* sodium hydroxide. Some precipitate separated at the neutral point, but redissolved on addition of excess alkali. This solution was shaken out with ether to remove phenylhydrazine and was then neutralized with dilute acetic acid. Impure II separated (m. p. 118–121°; reprecipitated from acid, m. p. 121–122°); yield 28.6 g. (26%). The yield of the combined pyrazolones was 97%.

Heating I with 5 *N* sulfuric acid gave a mixture from which only 40.5% V could be isolated. Heating of 10 g. I with 200 cc. of 20% acetic acid gave only 1.5 g. V.

Heating of I with Dilute Sodium Hydroxide.—A mixture of 10 g. of I and 100 cc. of 5 *N* sodium hydroxide and 10 cc. of alcohol was stirred and heated under reflux. Solution took place slowly, a yellow oil separating. After thirty minutes the solution was cooled and the separated oil (phenylhydrazine) extracted with benzene. The remaining solution was warmed with Nuchar, filtered and neutralized with dilute acetic acid. An oily precipitate of II separated. This crystallized on standing; yield 4.2 g. (61.5%); m. p. 123–125°.

Preparation of Other 3-Pyrazolones.—These preparations are sufficiently described in our patent[11] and only the following supplemental data are given here: 1. 1-(2′,5′-Dichlorophenyl)-5-methyl-3-pyrazolone (Example 4 of the patent): crude yield 97%, m. p. 231–235°; after recrystallization from benzene colorless crystals, m. p. 245–248° (cor.). Soluble in aqueous sodium hydroxide; poorly soluble in aqueous sodium carbonate. Diazotized *p*-nitraniline added to the alkaline solution produced a yellow azo dye.

Anal. Calcd. for $C_{10}H_8ON_2Cl_2$: C, 49.40; H, 3.32; N, 11.52. Found: C, 49.3; H, 3.3; N, 11.7.

2. 1 - (4′ - Nitrophenyl) - 5 - methyl - 3 - pyrazolone (Example 5 of the patent): yield after further purification by dissolving in dilute aqueous sodium hydroxide and reprecipitating with dilute acetic acid 88%, m. p. 230–234° (dec.); after recrystallization from alcohol yellow, fine needles m. p. 233–234° (dec., cor.). Readily soluble in aqueous sodium hydroxide, but difficultly in sodium carbonate. Diazotized *p*-nitraniline coupled with the alkaline solution to give a red-orange azo dye.

Anal. Calcd. for $C_{10}H_9O_3N_3$: C, 54.79; H, 4.14; N, 19.17. Found: C, 54.5; H, 4.3; N, 19.6.

3. 1 - (1′ - Naphthyl) - 5 - methyl - 3 - pyrazolone (Example 6 of the patent): Crude yield 81.4%, m. p. 240–241° (cor.) after recrystallizing from alcohol.

Anal. Calcd. for $C_{14}H_{12}ON_2$: C, 74.96; H, 5.39; N, 12.50. Found: C, 74.5; H, 5.2; N, 12.7.

1-(2′,5′-Dichlorophenyl)-3-methyl-5-pyrazolone.—A solution of 11.0 g. (0.085 mole) of acetoacetic ester and 15.0 g. (0.085 mole) of 2,5-dichlorophenylhydrazine in 100 cc. of glacial acetic acid was refluxed for seven hours. It was cooled and neutralized with aqueous sodium hydroxide. A slight residue remained when the solution was made alkaline. This was filtered and the alkaline filtrate neutralized

(14) Knorr, ref. 4, p. 171.

with dilute acetic acid. The pyrazolone separated as a sticky solid, crystallizing on standing; yield 18.2 g. (85.5%); recrystallized from alcohol, m. p. 173–173.5° (cor.).

Anal. Calcd. for $C_{10}H_8ON_2Cl_2$: N, 11.52. Found: N, 11.8.

If the Johnson[2] procedure is used for reaction of diketene and 2,5-dichlorophenylhydrazine, only little of the 5-pyrazolone is obtained, the main reaction product being the 2,5-dichlorophenylhydrazone of acetoacetic 2,5-dichlorophenylhydrazide. A solution of 4.2 g. (0.05 mole) of diketene in 25 cc. of benzene was dropped into a boiling solution of 8.8 g. (0.05 mole) of the hydrazine in 100 cc. of benzene; 60 cc. of benzene was distilled off. On cooling, 7.3 g. (69.4%) of the hydrazide crystallized (m. p. 188–189°) and the mother liquor gave on evaporation 1.5 g. (14.2% only) of impure 1-(2′,5′-dichlorophenyl)-3-methyl-5-pyrazolone (m. p. 161–163°).

Coupling Reactions of 1-Phenyl-5-methyl-3-pyrazolone (V).—In parallel experiments diazotized 2,5-diethoxy-4-benzoylamino-aniline was coupled on V and also on the isomeric 1-phenyl-3-methyl-5-pyrazolone (II) which is a very popular coupling component for azo dyestuffs. The pyrazolones were dissolved in dilute aqueous soda ash solution, V requiring more (3.5 mole) sodium carbonate than II (2.5 moles). The diazo solution was added at 5° and the alkalinity was adjusted to a faint test on Brilliant Yellow paper by adding sodium carbonate solution. II coupled very rapidly, precipitating bright, red crystals, m. p. 254.5–255.0° (cor.); yield 94%.

Anal. Calcd. for $C_{27}H_{27}O_4N_5$: C, 66.79; H, 5.61; N, 14.43. Found: C, 67.1; H, 5.70; N, 14.6.

The 3-pyrazolone (V) coupled much more slowly than did II and after thirty minutes a strong positive test for unreacted diazo was obtained with alkaline R Salt. Further addition of sodium carbonate to give a strong, alkaline test on Brilliant Yellow paper resulted in a more rapid disappearance of the R Salt test. This was negative after fifteen minutes, indicating complete reaction. The precipitated dye was filtered and dried; yield 4.0 g. (87.5%); recrystallized from alcohol as light brown crystals, m. p. 236.0–236.8° (cor.).

Anal. Calcd. for $C_{27}H_{27}O_4N_5$: C, 66.79; H, 5.61; N, 14.43. Found: C, 66.5; H, 5.60; N, 14.5.

A few other diazo components of commercial interest were diazotized and coupled on V; in all cases V coupled considerably slower than II.

Summary

1. At low temperature diketene and arylhydrazines give arylhydrazones of acetoacetic arylhydrazides in good yield. These seem to undergo a reversible thermal dissociation into aryl hydrazine and diketene-arylhydrazone which forms a 1-aryl-3-methyl-5-pyrazolone by internal ring closure. The latter reaction is enhanced if the arylhydrazine is removed from the equilibrium by the aid of diketene or by an undissociated acid.

2. If, on the other hand, the arylhydrazones of acetoacetic arylhydrazides are heated with strong, aqueous mineral acids, the hydrazone linkage is apparently hydrolyzed and the resulting acetoacetic arylhydrazide forms readily a 1-aryl-5-methyl-3-pyrazolone by internal ring closure. Heating with concentrated hydrochloric acid constitutes an excellent method for preparing these pyrazolones. The phenyl, the 2′,5′-dichlorophenyl, the 4′-nitrophenyl, and the 1′-naphthyl derivatives are dealt with.

3. The 1-aryl-5-methyl-3-pyrazolones couple with diazo compounds, but slower than the isomeric 1-aryl-3-methyl-5-pyrazolones.

4. A tautomeric diketene formula is briefly discussed.

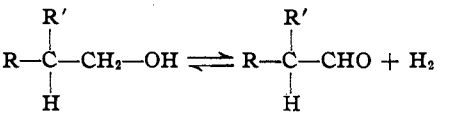
RECEIVED JUNE 28, 1944

[CONTRIBUTION FROM THE FRICK CHEMICAL LABORATORY OF PRINCETON UNIVERSITY]

Mechanism of Catalytic Hydrogenation and Dehydrogenation of Aldehydes and Alcohols

BY ELMER J. BADIN[1] AND EUGENE PACSU

Previous mechanisms for catalytic hydrogenation of carbonyl groups and catalytic dehydrogenation of alcohols. have usually pictured the carbonyl group itself and the hydrogens on the functional group as being involved. Since it appears to be a general phenomenon that the methylene group in a position *alpha* to a functional group contains reactive hydrogens, it seemed quite probable that carbon atom 2 should figure in the reaction. In order to determine whether the second carbon or an "enol" mechanism were involved, an optically active alcohol and the corresponding optically active aldehyde with asymmetry on carbon atom 2 were prepared and the reaction studied in the liquid phase and in the vapor phase



using nickel catalysts. Optically active compounds were selected as tracer compounds because any mechanism involving an activated state which would destroy the tetrahedral configuration would necessarily result in racemization and, further, exchange reactions such as are present in the deuterium hydrogenation–dehydrogenation equilibrium would not have to be considered.[1a]

(1) This paper is based upon a thesis submitted by Elmer J. Badin to the Faculty of Princeton University in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

(1a) An initial investigation regarding the mechanism was carried out by preparing a deutero alcohol in which the hydroxyl hydrogen was replaced by deuterium. This alcohol was prepared by shaking decanol-1 in a shaking mechanism with D_2O and the uptake of deuterium determined mass spectrographically. The deutero alcohol, after drying and distillation, was dehydrogenated in the liquid phase