iso*Cyanates. Part II.* The Hofmann Reaction with C-Benzoylformamide.*

By C. L. ARCUS and B. S. PRYDAL.

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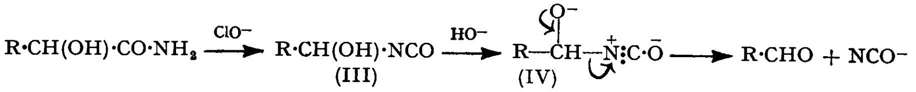
From a re-investigation of the Hofmann degradation of *C*-benzoylformamide to benzoic acid and cyanate ion (cf. Rinkes, *Rec. Trav. chim.*, 1929, **48**, 960) the reaction mechanism is concluded to be that represented by expression (3) (p. 4019).

THE mechanism (1) has been proposed for the Weerman degradation of α-hydroxy-amides (Part I *):

(1) 

$$R{\cdot}CH(OH){\cdot}CO{\cdot}NH_2 \xrightarrow{ClO^-} \underset{(III)}{R{\cdot}CH(OH){\cdot}NCO} \xrightarrow{HO^-} \underset{(IV)}{R{-}\overset{\displaystyle O^-}{\overset{|}{C}}H{-}\overset{+}{N}{:}C{\cdot}\bar{O}} \longrightarrow R{\cdot}CHO + NCO^-$$

In the hydroxy-*iso*cyanate (III) the electron-attracting *iso*cyanate group renders the hydroxyl-hydrogen atom weakly acidic, and the anion (IV) is formed; electronic movements as shown then yield the aldehyde and cyanate ion, the reaction as a whole being an elimination.

One other Hofmann reaction has been recorded in which a substantial amount of cyanate ion is formed: Rinkes (*Rec. Trav. chim.*, 1929, **48**, 960) found, qualitatively, that the reaction of benzoylformamide with alkaline hypochlorite yields sodium benzoate and sodium cyanate; he proposed course (2) for the reaction:

$$(2)\quad Ph{\cdot}CO{\cdot}CO{\cdot}NH_2 \xrightarrow{NaOH} \underset{(V)}{Ph{\cdot}C(OH)(ONa){\cdot}CO{\cdot}NH_2} \xrightarrow{NaOCl} Ph{\cdot}C(OH)(ONa){\cdot}NCO \xrightarrow{NaOH} Ph{\cdot}CO_2Na + NaCNO$$

Anhydrous benzoylformamide (m. p. 90°, Rinkes, *loc. cit.*; m. p. 90—91°, Claisen, *Ber.*, 1879, **12**, 632) is obtained only by rigorous drying of the material prepared by acidic hydrolysis of benzoyl cyanide. By the passage of carbon dioxide through a solution of the anhydrous amide in very dilute alkali, Claisen (*loc. cit.*) obtained a material which, when air-dried, had m. p. 64—65° and gave analyses in agreement with its formulation as a monohydrate. On drying over sulphuric acid it slowly lost water. In accordance with these observations, Rinkes postulated the formation of the sodium salt of the monohydrate (V), prior to the reaction with hypochlorite. This author's course (2) for the reaction is now substantiated.

The reaction of rigorously dried *C*-benzoylformamide with aqueous alkaline hypochlorite yielded 76—81% of benzoic acid and 73—83% of cyanate (isolated as hydrazinedicarbonamide); the amide, m. p. 83—85°, which had been recrystallised but not subjected to rigorous drying, gave similar results, 78% of benzoic acid and 80—83% of hydrazine dicarbonamide.

Billeter (*Ber.*, 1903, **36**, 3218) found that benzoyl *iso*cyanate and water rapidly yield benzamide, carbon dioxide, and dibenzoylurea:

$$Ph{\cdot}CO{\cdot}NCO + H_2O \longrightarrow Ph{\cdot}CO{\cdot}NH_2 + CO_2 \ (70\text{—}75\%)$$

$$Ph{\cdot}CO{\cdot}NCO + Ph{\cdot}CO{\cdot}NH_2 \longrightarrow CO(NH{\cdot}CO{\cdot}Ph)_2 \ (25\text{—}30\%)$$

It has now been found that benzoyl *iso*cyanate reacts vigorously with aqueous alkali, to yield nearly pure benzamide (73% isolated) and only a trace of cyanate ion. The reaction resembles the alkaline hydrolysis of an alkyl *iso*cyanate to an amine: $Ph{\cdot}CO{\cdot}NCO + 2HO^- \longrightarrow Ph{\cdot}CO{\cdot}NH_2 + CO_3^{2-}$. It is apparent that benzoyl *iso*cyanate, the "normal" product of the Hofmann reaction with benzoylformamide, cannot be

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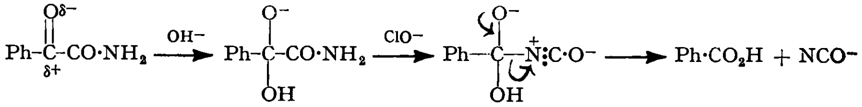
* A paper entitled "The Hofmann Reaction with α- and β-Hydroxy-amides: Reactions of the Intermediate *iso*Cyanates" (Arcus and Greenwood, *J.*, 1953, 1937) is regarded as Part I.

formed during the reaction with aqueous alkaline hypochlorite. It is concluded, therefore, that interaction of benzoylformamide with hydroxyl ion precedes conversion of the amide group into *iso*cyanate, and the mechanism (3) is proposed for the complete reaction, the electronic movements being identical with those proposed for the Weerman reaction:

(3)



$$Ph\text{-}\overset{O^{\delta-}}{\underset{\delta+}{C}}\text{-}CO\cdot NH_2 \xrightarrow{OH^-} Ph\text{-}\overset{O^-}{\underset{OH}{C}}\text{-}CO\cdot NH_2 \xrightarrow{ClO^-} Ph\text{-}\overset{O^-}{\underset{OH}{C}}\text{-}\overset{+}{N}\text{:}C\cdot O^- \longrightarrow Ph\cdot CO_2H + NCO^-$$

EXPERIMENTAL

C-Benzoylformamide was prepared by a modification of Claisen's method (*loc. cit.*). Concentrated hydrochloric acid (100 ml.) was saturated at 0° by the passage of hydrogen chloride; crushed benzoyl cyanide (50 g.; *Org. Synth.*, 1944, **24**, 14) was then added and the whole was shaken until a clear solution was obtained (2—6 hr.). The solution was cooled in ice and poured into water; after 1 hr. the solid was filtered off; a further quantity separated from the filtrate and was collected next day. The benzoylformamide so obtained (46 g.; m. p. 66—69°), recrystallised from ethanol, had m. p. 83—85° (Found: N, 8·65. Calc. for $C_8H_7O_2N,H_2O$: N, 8·4. Calc. for $C_8H_7O_2N$: N, 9·4%). After long drying *in vacuo* over sulphuric acid, and after being kept over phosphoric oxide at 45—50°/0·05 mm. for 1 hr., benzoylformamide had m. p. 90—90·5° (Found: N, 9·15%).

Hofmann Reaction.—Benzoylformamide [expts. (i), (ii) 2·48 g.; m. p. 90—90·5°] was added to ice-cooled, stirred alkaline hypochlorite solution (1·0N in NaOCl, 1·5N in NaOH; 67 ml.); the mixture was warmed to 34°, at which temperature the amide dissolved. Stirring was continued for 1 hr.; the excess of hypochlorite was removed by addition of aqueous sodium sulphite (36%). Semicarbazide hydrochloride (1·85 g.) was added; the solution was cooled in ice and brought to pH 3·8 by 2N-sulphuric acid; a solid commenced to separate. The whole was heated on a steam-bath for 20 min., cooled, and filtered. The precipitate was stirred for 1 hr. with cold N-sodium carbonate (50 ml.), then filtered off, washed with water, and dried. The hydrazinedicarbonamide so obtained [(i) 1·4 g., m. p. 246—247°; (ii) 1·6 g., m. p. 247—248°] had, after recrystallisation from hot water, m. p. and mixed m. p. 249—249·5°.

A control experiment, in which alkaline hypochlorite solution was successively treated with the reagents as above, gave no precipitate.

The sodium carbonate filtrate and washings were strongly acidified with 10N-sulphuric acid, and chilled; benzoic acid (*A*) separated. The filtrate from the preparation of hydrazin dicarbonamide similarly gave benzoic acid (*B*). Ether-extraction of the filtrates from (*A*) and (*B*) yielded a further quantity (*C*). Combination of (*A*), (*B*), and (*C*) gave benzoic acid [(i) 1·5 g., m. p. 119—121·5°; (ii) 1·6 g., m. p. 119·5—120·5°] which, after recrystallisation from hot water, had m. p. and mixed m. p. 121—122° (benzyl *iso*thiuronium salt, m. p. and mixed m. p. 166—166·5°).

Two similar experiments were carried out with benzoylformamide [(i), (ii) 2·48 g.] having m. p. 83—85°; in the second a double quantity of semicarbazide hydrochloride was added. There were obtained hydrazinedicarbonamide [(i) 1·5 g., (ii) 1·45 g.; each m. p. 245—246°] and benzoic acid [(i) 1·45 g., m. p. 120·5—122°; (ii) 1·45 g., m. p. 121—122°].

Benzoyl iso*Cyanate.*—A solution of benzoyl chloride (28·1 g.) in carbon tetrachloride (96 ml.; dried over P_2O_5) was added dropwise to a stirred suspension of silver cyanate (34·5 g., dried over P_2O_5 and powdered) in carbon tetrachloride (50 ml.). The whole was heated under reflux for 6 hr.; carbon tetrachloride was then distilled from the filtered solution. The product on distillation yielded benzoyl *iso*cyanate (13·6 g., 46%), b. p. 94—96°/21 mm.; it solidified on cooling. This preparation appears more satisfactory than those of Billeter (*loc. cit.*) and Hill and Degnan (*J. Amer. Chem. Soc.*, 1940, **62**, 1595) who record, respectively, b. p. 88°/10 mm. and 88—91°/20 mm.

Benzoyl *iso*cyanate (2·65 g.) was added to N-sodium hydroxide (60 ml.); a vigorous reaction occurred and a white solid separated which was filtered off and dried. It (1·6 g.) had m. p. 124—125·5°, and, after recrystallisation from hot water, m. p. and mixed m. p. 126—126·5°. A portion of the filtrate, above, was treated with pyridine, acetic acid (sufficient to render the solution acid), chloroform, and 1% aqueous copper sulphate; the chloroform layer acquired a slight blue colour, indicating a little cyanate to be present; however, on treatment of the greater part of the filtrate with semicarbazide hydrochloride and acetic acid, an opalescence only was developed.

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