437. *The Action of Chlorine, Bromine, and Iodine Monochloride upon Arylazoacetoacetates and Related Compounds.*

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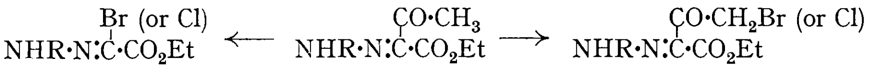
IN acetic acid at the ordinary temperature in the presence of sodium acetate, bromine replaces the acetyl group of *ethyl* 2 : 4-*dinitrophenylazoacetoacetate, ethyl* α-*bromoglyoxylate*-2 : 4-*dinitrophenylhydrazone* being formed. In the absence of sodium acetate, in boiling acetic acid, however, bromine is substituted for hydrogen in the acetyl group and *ethyl* 2 : 4-*dinitrophenylazo*-γ-*bromoacetoacetate* is formed.



$$\overset{\text{Br (or Cl)}}{\mathrm{NHR{\cdot}N{:}C{\cdot}CO_2Et}} \longleftarrow \overset{\mathrm{CO{\cdot}CH_3}}{\mathrm{NHR{\cdot}N{:}C{\cdot}CO_2Et}} \longrightarrow \overset{\mathrm{CO{\cdot}CH_2Br}\text{ (or Cl)}}{\mathrm{NHR{\cdot}N{:}C{\cdot}CO_2Et}}$$

Chlorine appears to have no action on a solution of ethyl 2 : 4-dinitrophenylazoacetoacetate in cold or boiling acetic acid, or cold or boiling chloroform, and the starting material can be recovered unchanged. When, however, action takes place in cold acetic acid containing crystalline sodium acetate, chlorine replaces the acetyl group as a whole and *ethyl* α-*chloroglyoxylate*-2 : 4-*dinitrophenylhydrazone* is formed. Action also occurs if carefully dried chloroform is the solvent, and a quantitative yield of *ethyl* 2 : 4-*dinitrophenylazo*-γ-*chloroacetoacetate* is then obtained.

Similarly, chlorine does not attack 2 : 4-*dinitrophenylazoacetylacetone* or 2 : 4-*dinitrophenylazobenzoylacetone* in cold or boiling acetic acid or in cold or boiling chloroform, even when perfectly dry; but when a solution of either of these compounds in acetic acid contains crystalline sodium acetate, the acetyl group is replaced by chlorine and ω-*chloro*-α-*ketopropaldehyde*-2 : 4-*dinitrophenylhydrazone* and ω-*chlorophenylglyoxal*-2 : 4-*dinitrophenylhydrazone*, respectively, are formed :

$$\mathrm{CH_3{\cdot}CO{\cdot}C({:}N{\cdot}NHR){\cdot}CO{\cdot}CH_3}\text{ (or Ph)} \longrightarrow \mathrm{Cl{\cdot}C({:}N{\cdot}NHR){\cdot}CO{\cdot}CH_3}\text{ (or Ph)}$$

The action of iodine monochloride upon the arylazoacetoacetates is considerably influenced, and in some instances completely altered, by the nature of the groups present in the phenyl nucleus.

Thus when iodine monochloride reacts with ethyl 2 : 4 : 6-tribromo-, 2 : 4-dibromo-, *p*-bromo-, *p*-nitro-, or *o*-nitro-phenylazoacetoacetate dissolved in acetic acid, iodine is substituted in the acetyl group and the corresponding γ-iodo-compound is formed, the yield in every case being good (80%).

$$\mathrm{CH_3{\cdot}CO{\cdot}C({:}N{\cdot}NHR){\cdot}CO_2Et} \longrightarrow \mathrm{CH_2I{\cdot}CO{\cdot}C({:}N{\cdot}NHR){\cdot}CO_2Et}$$

With 2 : 4-dinitrophenylazoacetoacetate, however, iodine is liberated and ethyl 2 : 4-dinitrophenylazo-γ-chloroacetoacetate is formed, the yield here also being good (70%) :

$$\mathrm{CH_3{\cdot}CO{\cdot}C({:}N{\cdot}NHR'){\cdot}CO_2Et} \longrightarrow \mathrm{CH_2Cl{\cdot}CO{\cdot}C({:}N{\cdot}NHR'){\cdot}CO_2Et}$$

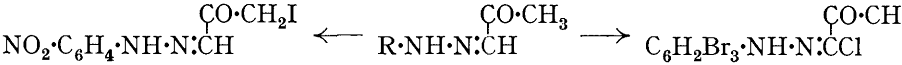
An excess of iodine monochloride does not in any case carry the reaction further.

When, however, iodine monochloride acts upon ethyl *p*-chlorophenylazoacetoacetate in acetic acid, the acetyl group is replaced by chlorine and ethyl α-chloroglyoxylate-*p*-chlorophenylhydrazone is formed. Iodine monochloride similarly replaces the acetyl group in ethyl phenylazoacetoacetate by chlorine, and in addition substitutes iodine in the para-position of the phenyl nucleus, ethyl α-chloroglyoxylate-*p*-iodophenylhydrazone being produced, which on reduction with tin and hydrochloric acid yields *p*-iodoaniline (identified by its acetyl derivative) :

$$\mathrm{CH_3{\cdot}CO{\cdot}C({:}N{\cdot}NHR''){\cdot}CO_2Et} \longrightarrow \mathrm{Cl{\cdot}C({:}N{\cdot}NHR''){\cdot}CO_2Et}$$

Although in the latter two cases the yield was poor (20%), no other product could be isolated.

The action of iodine monochloride upon an acetic acid solution of α-ketopropaldehyde-*o*-nitrophenylhydrazone (I) produces β-iodo-α-ketopropaldehyde-*o*-nitrophenylhydrazone (II) in good yield, but its action upon the corresponding 2 : 4 : 6-tribromo-compound under similar conditions yields ω-chloro-α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone (III), though only in poor yield (20%) :

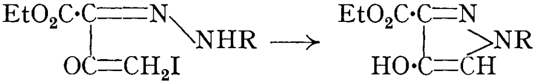


$$\mathrm{NO_2{\cdot}C_6H_4{\cdot}NH{\cdot}N{:}\overset{CO\cdot CH_2I}{CH}} \longleftarrow \mathrm{R{\cdot}NH{\cdot}N{:}\overset{CO\cdot CH_3}{CH}} \longrightarrow \mathrm{C_6H_2Br_3{\cdot}NH{\cdot}N{:}\overset{CO\cdot CH_3}{CCl}}$$

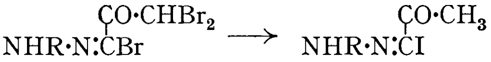
(II.) (I.) (III.)

The arylazoacetylacetones and the arylazobenzoylacetones did not react with iodine monochloride under any of the conditions tried and were recovered unchanged.

The iodine substituted in the acetyl group is very reactive. Thus, on treating the γ-iodo-compounds with potassium acetate, hydrogen iodide is eliminated and ring closure takes place with the formation of pyrazoles, identical with those obtained from the corresponding γ-chloro- and γ-bromo-compounds (*Proc. Roy. Soc.*, 1932, *A*, **135**, 282; **137**, 489; J., 1933, 475, 1143) :



When any one of the arylazo-γ-bromo- or -chloro-acetoacetates is treated with potassium iodide in alcoholic solution, the halogen is replaced by iodine. Thus ethyl *p*-nitrophenylazo-γ-chloroacetoacetate yields ethyl *p*-nitrophenylazo-γ-iodoacetoacetate. When, however, ββω-tribromo-α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone is similarly treated in acetic acid solution, ω-iodo-α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone is formed :

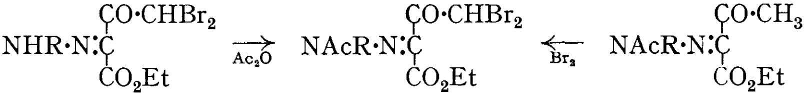


$$\mathrm{NHR{\cdot}N{:}\overset{CO\cdot CHBr_2}{CBr}} \longrightarrow \mathrm{NHR{\cdot}N{:}\overset{CO\cdot CH_3}{CI}}$$

The arylazoacetoacetates are not easily acetylated; for example, ethyl 2 : 4-dibromo-, 2 : 4-dichloro-, *p*-nitro-, and *o*-nitro-phenylazoacetoacetates can be recovered unchanged after heating with acetic anhydride. Heating in a sealed tube with acetyl chloride causes decomposition.

Ethyl 2 : 4 : 6-tribromo- and 2 : 4 : 6-trichloro-phenylazoacetoacetates, however, yield *N*-acetyl derivatives when warmed with acetic anhydride containing a drop of sulphuric acid (*Proc. Roy. Soc.*, 1932, *A*, **135**, 282).

When chlorine is passed into a solution of either of these *N*-acetyl derivatives, dissolved in glacial acetic acid, with or without the addition of sodium acetate, or in moist or dry chloroform, whether at the ordinary temperature or at the boiling point of the solvent, no action at all takes place and the starting material can be recovered quantitatively unchanged. Similarly bromine has no action upon these acetyl compounds when dissolved in cold or boiling acetic acid containing crystalline sodium acetate. When, however, excess of bromine is added to a solution of either of these compounds in boiling acetic acid or chloroform, the halogen substitutes at once in the aceto-group, and two hydrogen atoms are replaced by bromine, *ethyl* 2 : 4 : 6-*tribromo-* or 2 : 4 : 6-*trichloro-phenylazo-γγ-dibromoacetoacetate*-N-*acetate* being formed, identical with the compounds obtained by heating ethyl 2 : 4 : 6-tribromo- or 2 : 4 : 6-trichloro-phenylazo-γγ-dibromoacetoacetate with acetic anhydride :



$$\mathrm{NHR{\cdot}N{:}\underset{CO_2Et}{\overset{CO\cdot CHBr_2}{C}}} \xrightarrow{Ac_2O} \mathrm{NAcR{\cdot}N{:}\underset{CO_2Et}{\overset{CO\cdot CHBr_2}{C}}} \xleftarrow{Br_2} \mathrm{NAcR{\cdot}N{:}\underset{CO_2Et}{\overset{CO\cdot CH_3}{C}}}$$

The replacement of the imino-hydrogen atom by an acetyl group, while not hindering substitution in the acetyl group, yet prevents the replacement of this group as a whole by halogen (cf. *loc. cit.*).

EXPERIMENTAL.

By the procedure previously given (Chattaway and Ashworth, J., 1933, 475, 1624), the following have been prepared :

Ethyl 2 : 4-*dinitrophenylazoacetoacetate*, yellow slender prisms from alcohol, m. p. 108° (Found : N, 17·0. $C_{12}H_{12}O_7N_4$ requires N, 17·3%).

2 : 4-*Dinitrophenylazobenzoylacetone*, yellow slender prisms from acetic acid, m. p. 203° (Found : N, 15·8. $C_{16}H_{12}O_6N_4$ requires N, 15·7%).

2 : 4-*Dinitrophenylazoacetylacetone*, irregular, fragile, flattened prisms from acetic acid, m. p. 176° (Found : N, 19·0. $C_{11}H_{10}O_6N_4$ requires N, 19·05%).

Ethyl α-*bromoglyoxylate*-2 : 4-*dinitrophenylhydrazone*, yellow, very long, slender prisms from alcohol, m. p. 122° (Found : Br, 22·1. $C_{10}H_9O_6N_4Br$ requires Br, 22·2%).

Ethyl α-*aminoglyoxylate*-2 : 4-*dinitrophenylhydrazone*, red slender prisms from alcohol, m. p. 169° (Found : N, 23·6. $C_{10}H_{11}O_6N_5$ requires N, 23·6%).

Ethyl 2 : 4-*dinitrophenylazo*-γ-*bromoacetoacetate*, yellow needles from alcohol, m. p. 141° (Found : Br, 19·7. $C_{12}H_{11}O_7N_4Br$ requires Br, 19·9%).

4-*Hydroxy*-3-*carbethoxy*-1-(2′ : 4′-*dinitrophenyl*)*pyrazole*, colourless, flattened, rectangular prisms from alcohol, m. p. 150° (Found : N, 17·2. $C_{12}H_{10}O_7N_4$ requires N, 17·4%).

Action of Dry Chlorine upon Ethyl 2 : 4-*Dinitrophenylazoacetoacetate in Dry Chloroform*.—5 G. of ethyl 2 : 4-dinitrophenylazoacetoacetate were dissolved in 15 c.c. of carefully dried, redistilled chloroform and dry chlorine was passed for 20 minutes with the careful exclusion of moisture. On evaporation of the solvent on a water-bath *ethyl* 2 : 4-*dinitrophenylazo*-γ-*chloroacetoacetate* remained as a yellow solid. It crystallised from alcohol in yellow, long, slender prisms, m. p. 143° (Found : Cl, 9·6. $C_{12}H_{11}O_7N_4Cl$ requires Cl, 9·9%).

Action of Chlorine upon Ethyl 2 : 4-*Dinitrophenylazoacetoacetate in Acetic Acid in the Presence of Sodium Acetate*.—5 G. of ethyl 2 : 4-dinitrophenylazoacetoacetate and 5 g. of crystalline sodium acetate were suspended in 10 c.c of cold acetic acid, and chlorine passed for 20 minutes. On careful addition of water to the resulting solution *ethyl* α-*chloroglyoxylate*-2 : 4-*dinitrophenylhydrazone* separated as a viscous yellow mass, which crystallised from alcohol in long, slender, flattened prisms, m. p. 120° (Found : Cl, 11·1. $C_{10}H_9O_6N_4Cl$ requires Cl, 11·2%).

Similarly, from 2 : 4-dinitrophenylazobenzoylacetone was obtained ω-*chlorophenylglyoxal*-2 : 4-*dinitrophenylhydrazone*, yellow, flattened, irregular prisms from acetic acid, m. p. 177° (Found : Cl, 10·3. $C_{14}H_9O_5N_4Cl$ requires Cl, 10·2%), and from 2 : 4-dinitrophenylazoacetylacetone, ω-*chloro*-α-*ketopropaldehyde*-2 : 4-*dinitrophenylhydrazone*, yellow, large, irregular, rhombic plates from acetic acid, m. p. 159° (Found : Cl, 12·7. $C_9H_7O_5N_4Cl$ requires Cl, 12·4%).

Iodine monochloride was prepared by the action of chlorine upon finely divided iodine suspended in acetic acid (Chattaway and Constable, J., 1914, **105**, 124). Using 12·7 g. of iodine in 15 c.c. of acetic acid, a solution of iodine monochloride was obtained, of which 2 c.c. contained 1·27 g. of iodine. This solution was used in all cases below.

Formation of Ethyl 2 : 4 : 6-*Tribromophenylazo*-γ-*iodoacetoacetate*.—2 C.c. of iodine monochloride solution (above) were added to 4·7 g. of ethyl 2 : 4 : 6-tribromophenylazoacetoacetate dissolved in 20 c.c. of cold acetic acid, and the whole left for 2 hours; *ethyl* 2 : 4 : 6-*tribromophenylazo*-γ-*iodoacetoacetate* then separated. After being washed with a little aqueous sodium sulphite, it crystallised from chloroform–light petroleum in yellow, long, slender prisms, m. p. 104° (Found : Br, 40·0; I, 21·1. $C_{12}H_{10}O_3N_2Br_3I$ requires Br, 40·2; I, 21·3%).

Similarly were prepared : *Ethyl* 2 : 4-*dibromophenylazo*-γ-*iodoacetoacetate*, yellow, long, slender prisms from alcohol, m. p. 127° (Found : Br, 31·1; I, 24·7. $C_{12}H_{11}O_3N_2Br_2I$ requires Br, 30·9; I, 24·5%), *ethyl* p-*bromophenylazo*-γ-*iodoacetoacetate*, yellow, long, slender, somewhat flattened prisms from alcohol, m. p. 114° (Found : Br, 18·0; I, 28·6. $C_{12}H_{12}O_3N_2BrI$ requires Br, 18·2; I, 28·9%), *ethyl* p-*nitrophenylazo*-γ-*iodoacetoacetate*, yellow, long, slender, rectangular prisms from alcohol, m. p. 154° (Found : I, 31·1. $C_{12}H_{12}O_5N_3I$ requires I, 31·3%), and *ethyl* o-*nitrophenylazo*-γ-*iodoacetoacetate*, yellow, long, slender, somewhat flattened prisms from alcohol, m. p. 128° (Found : I, 31·4%).

These compounds were also obtained by heating the corresponding γ-chloro- or γ-bromo-compound with potassium iodide in alcoholic solution; *e.g.*, 1 g. of ethyl *p*-nitrophenylazo-γ-chloroacetoacetate and 1 g. of potassium iodide were refluxed for 10 minutes in 15 c.c. of alcohol; ethyl *p*-nitrophenylazo-γ-iodoacetoacetate then separated identical with the compound prepared as above.

Ethyl 2 : 4-*Dinitrophenylazo*-γ-*chloroacetoacetate*.—2 C.c. of iodine monochloride solution were added to a solution of 2 g. of ethyl 2 : 4-dinitrophenylazoacetoacetate in 5 c.c. of cold acetic acid. After an hour the above compound separated, much iodine being liberated. On crystallisation from alcohol it was shown to be identical with the compound obtained by the action of chlorine upon ethyl 2 : 4-dinitrophenylazoacetoacetate in dry chloroform solution (see above).

Formation of Ethyl α-*Chloroglyoxylate*-p-*iodophenylhydrazone*.—10 C.c. of iodine monochloride were added to 5 g. of ethyl phenylazoacetoacetate, dissolved in 15 c.c. of cold acetic acid, and the whole kept for 3 hours; the above *compound* then separated in 15% yield. It crystallised from alcohol in colourless short needles, m. p. 176° (Found : Cl, 10·0; I, 36·1. $C_{10}H_{10}O_2N_2ClI$ requires Cl, 10·0; I, 36·0%). Similarly from ethyl *p*-chlorophenylazoacetoacetate was obtained ethyl α-chloroglyoxylate-*p*-chlorophenylhydrazone, identical with an authentic specimen (*Proc. Roy. Soc.*, 1932, *A*, **137**, 489).

β-*Iodo-α-ketopropaldehyde*-o-*nitrophenylhydrazone*.—2 C.c. of iodine monochloride solution were added to 2 g. of α-ketopropaldehyde-*o*-nitrophenylhydrazone in 15 c.c. of acetic acid at 40° On standing over-night, the above *compound* separated; it crystallised from alcohol in yellow slender prisms, m. p. 174° (Found : I, 38·0. $C_9H_8O_3N_3I$ requires I, 38·2%).

Similarly, from α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone was obtained ω-chloro-α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone, which after crystallisation was identical with an authentic specimen (this vol., p. 934).

ω-*Iodo-α-ketopropaldehyde*-o-*nitrophenylhydrazone* was prepared by refluxing 2 g. of ω-bromo-α-ketopropaldehyde with 3 g. of potassium iodide in 100 c.c. of alcohol for 3 hours. It crystallised from acetic acid in yellow, long, flattened prisms, m. p. 189° (Found : I, 38·5%).

Similarly were prepared : ω-*iodo-α-ketopropaldehyde*-2 : 4-*dibromophenylhydrazone*, very pale yellow, felted masses of long hair-like needles from alcohol, m. p. 169° (Found : Br, 36·0; I, 28·5. $C_9H_7ON_2Br_2I$ requires Br, 35·9; I, 28·5%), and ω-*iodo-α-ketopropaldehyde*-2 : 4 : 6-*tribromophenylhydrazone*, very pale yellow, long, slender prisms from alcohol, m. p. 150° (Found : Br, 45·9; I, 24·3; N, 5·0. $C_9H_6ON_2Br_3I$ requires Br, 45·7; I, 24·2; N, 5·3%).

Action of Potassium Iodide upon ββω-*Tribromo-α-ketopropaldehyde*-2 : 4 : 6-*tribromophenylhydrazone*.—2 G. of potassium iodide in 10 c.c. of water were added to 2 g. of ββω-tribromo-α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone in 30 c.c. of acetic acid at 100°, and the whole heated on a water-bath for 4 hours. On cooling, the above compound separated and on crystallisation was shown to be identical with an authentic specimen (see above).

The same product was also obtained on similar treatment of βω-*dibromo-α-ketopropaldehyde*-2 : 4 : 6-*tribromophenylhydrazone*, which was prepared by the action of 2 mols. of bromine upon α-ketopropaldehyde-2 : 4 : 6-tribromophenylhydrazone, and crystallised from alcohol in yellow, long, slender rectangular prisms, m. p. 134° (Found : Br, 72·0. $C_9H_5ON_2Br_5$ requires Br, 71·8%).

Formation of Ethyl 2 : 4 : 6-*Tribromophenylazo-γγ-dibromoacetoacetate*-N-*acetate*.—(I) 2·4 G. of bromine in 3 c.c. of acetic acid were added to 4 g. of ethyl 2 : 4 : 6-tribromophenylazoacetoacetate-*N*-acetate dissolved in 10 c.c. of boiling acetic acid. On addition of water to the resulting solution the above *compound* separated. It crystallised from alcohol in colourless rectangular prisms with domed ends, m. p. 178° (Found : Br, 59·7. $C_{14}H_{11}O_4N_2Br_5$ requires Br, 59·6%).

(II) 2 G. of ethyl 2 : 4 : 6-tribromophenylazo-γγ-dibromoacetoacetate were heated with 5 c.c. of acetic anhydride containing a drop of sulphuric acid. On addition of water a colourless solid separated which on crystallisation was found to be identical with the above acetyl derivative.

In a similar manner to (I) above was obtained *ethyl* 2 : 4 : 6-*trichlorophenylazo-γγ-dibromoacetoacetate*-N-*acetate*, which formed colourless, compact, irregular prisms from alcohol, m. p. 141° (Found : Cl, 19·8; Br, 29·8. $C_{14}H_{11}O_4N_2Cl_3Br_2$ requires Cl, 19·8; Br, 29·8%).

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