THE REACTION OF SOME SODIUM SALTS OF FATTY ACIDS AND
BENZOIC ACID WITH $\alpha$-BROMOBENZYL CYANIDE

by

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A thesis submitted in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE
in
CHEMISTRY
1953

UTAH STATE AGRICULTURAL COLLEGE
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Fife (4) and O'Shaughnessy (12) have made a series of di-esters by allowing the sodium salts of various fatty acids to react with ethyl monochloracetate according to the following equation:

\[ \text{RCO}_2\text{Na} + \text{ClCH}_2\text{CO}_2\text{C}_2\text{H}_5 \rightarrow \text{RCO}_2\text{CH}_2\text{CO}_2\text{C}_2\text{H}_5 + \text{NaCl} \]

The mechanism of the reaction appears to be ionic and to involve the attack of an \( \text{RCO}_2^- \) ion on the carbon atom to which the chlorine atom is attached. As the \( \text{RCO}_2^- \) approaches this carbon atom the chlorine atom moves away and leaves as a chloride ion. This reaction appears to be similar to the Williamson synthesis of ethers:

\[ \text{RONa} + \text{R'}\text{X} \rightarrow \text{ROR'} + \text{NaX} \]

According to Alexander (2) the Williamson synthesis normally proceeds by an \( S_n^2 \) mechanism, involving first the ionization of the sodium salt followed by an attack of the alkoxide ion on the carbon atom to which the halogen is attached:

\[ \text{RO} + \text{X} \rightarrow \text{ROC} + \text{X} \]

It therefore seems reasonable to assume that the reactions carried out by Fife (4) and O'Shaughnessy (12) involved first an ionization of the sodium alkanoate; and second, the attack of the halogen containing carbon atom by the alkanoate ion.

The ease with which a halogen ion could be removed from any carbon atom depends on the other groups attached to this same carbon atom. In the above cases studied by Fife (4) and O'Shaughnessy (12) the presence of the negative carboxy group attached to the same carbon atom as the
chlorine atom should facilitate the approach of the alkanoate ion to this carbon atom, and allow the chlorine atom to escape more readily as a negative ion than in cases where the chlorine atom is attached to an alkyl group.

Since the presence of a negative group makes the halogen atom more reactive in ethyl chloroacetate, it would be expected that in other cases where a halogen atom is attached to a carbon atom—which, in turn, is attached to one or more negative groups—similar reactivity could be anticipated. The more negative groups attached to the carbon, the more reactive the halogen should be to displacement reactions, excluding steric effects.

α-bromobenzyl cyanide would appear to furnish a typical example of a compound with two activating negative groups. It contains two negative groups—a phenyl group and a cyanide group—attached to the halogen containing carbon atom. From the point of view of the theory of resonance, five resonance forms could be written for the carbonium ion obtained on loss of the halogen ion, whereas in the case of ethyl chloroacetate only two resonance forms can be written. This indicates that the halogen atom should be much easier lost from the α-bromobenzyl cyanide than in the case of the halogen in ethyl chloroacetate. The resonance stabilization of the carbonium ion resulting from loss of bromine from α-bromobenzyl cyanide is greater than the resonance stabilization of the unionized compound. The resonance forms are illustrated as follows:
Although it is not likely that the halogen is lost completely before the alkanoate ion becomes attached, the fact that it is more easily displaced in α-bromobenzyl cyanide than in ethyl chloroacetate would make the former compound more reactive.

The reaction of α-bromobenzyl cyanide with sodium alkanoates would be expected to proceed by the same mechanism as given for the Williamson synthesis of ethers. The sodium alkanoate would first ionize, followed by an $S_N2$ replacement of the halogen atom by the nucleophilic alkanoate ion:

$$\text{RCO}_2^- + C_6H_5C-CN \rightarrow C_6H_5C-CN^- + \text{Br}^-$$

This problem was undertaken to increase the knowledge of reactions of the sodium salts of fatty acids and to find out more about the reactions of active halogen compounds.
This research concerns the reaction of α-bromobenzyl cyanide with the sodium salts of the following acids: formic, acetic, propionic, butyric, isobutyric, valeric, isovaleric, methylethyl acetic, trimethyl acetic, and benzoic acid.

Mandelonitrile acetate (11) and benzoate (6, 10) have been prepared previously but by different methods.

Mandelonitrile acetate was first prepared by Michael and Jeanpretre (11) in 1892 by refluxing equal molar quantities of mandelonitrile and acetic anhydride for three hours. A quantitative yield of mandelonitrile acetate was obtained, b.p. 153 degrees C. (25 mm.). The boiling point of this compound has also been reported (3) 137.8 degrees C. (11 mm.).

Mandelonitrile benzoate was first prepared by Francis and Davis (6) in 1909. Benzoyl chloride, benzaldehyde, and potassium cyanide were allowed to react with stirring. A quantitative yield of mandelonitrile benzoate was obtained, m.p. 63-64 degrees C.

Mandelonitrile benzoate was later prepared by Marvel, Brace, Miller, and Johnson (10) in 1947 by allowing benzoyl cyanide and benzaldehyde to react in five percent aqueous potassium hydroxide solution. A 49 percent yield was obtained, m.p. 59 degrees C.
DISCUSSION

α-Bromobenzyl cyanide, anhydrous salts of fatty acids, and benzoic acid were used in this problem. The α-bromobenzyl cyanide was prepared from benzyl chloride (1, 13). Benzyl cyanide was prepared following the directions of Adams and Thal (1) by the action of sodium cyanide on benzyl chloride. The benzyl cyanide was purified by rectification in the Podbielniak Column, 25 mm., 48" (8). The α-bromobenzyl cyanide was prepared as needed, according to a procedure of Robb and Schultz (13), in which benzyl cyanide was allowed to react with bromine.

It was necessary to prepare some of the sodium salts of fatty acids. These were prepared by the reaction of the fatty acids with aqueous sodium hydroxide.

The esters of mandelonitrile with the various acids concerned were prepared by allowing α-bromobenzyl cyanide to react with an excess of the sodium salts of the acids.

Some mandelonitrile esters also were prepared by using an excess of the α-bromobenzyl cyanide; however, it was difficult to remove the last traces of the α-bromobenzyl cyanide—a powerful lacrymator—by this method, so this procedure was abandoned. The reaction also was carried out using dioxane as a diluent but no increase in yield was obtained by using it.

The specific gravities of the esters were measured following the directions of Shriner and Fuson (15). The calculations were made as follows:
Wt. in grams of pycnometer 6.5848
Wt. in grams of pycnometer + H₂O 8.3500

\[
\text{Wt. H₂O} = 1.7652
\]

\[
\text{Sp. Gr.} = \frac{\text{Wt. of sample}}{1.7652}
\]

The combustion analyses were made according to the directions given by Fisher (5). The following method of calculation was used:

\[
\text{Percent of H} = \frac{\text{Wt. of H₂O} \times 2.016 \times 100}{\text{Wt. of sample} \times 18.016}
\]

\[
\text{Percent of C} = \frac{\text{Wt. of CO₂} \times 3 \times 100}{\text{Wt. of sample} \times 11}
\]

The analyses for nitrogen were made by the Kjeldahl method outlined by Scott (14). The calculations were made as follows:

\[
\% \text{N} = \frac{(\text{ml. acid} \times \text{normality}) - (\text{ml. base} \times \text{normality}) \times 14 \times 100}{\text{Wt. sample} \times 1,000}
\]

Molecular refractions were obtained according to the method outlined by Gibb (7). Calculations were made as follows:

\[
M_r (\text{obs.}) = \frac{n^2 - 1}{n^2 + 2} \cdot M_d
\]

\[M_r (\text{calc.})\] was obtained by using the Eisenlohr atomic refractions listed by Gibb (7): C = 2.418; O (carboxyl) = 2.211; O (ether) = 1.643; H = 1.100; CN = 5.459; C = C (double bond) = 1.733.
**EXPERIMENTAL**

**Benzyl Cyanide**

The procedure outlined by Adams and Thal (1) was used in the preparation of this compound. In a 5 l. three-necked, round-bottomed flask fitted with a mechanical stirrer, a reflux condenser, and a separatory funnel, were placed 500 g. (10 moles) of powdered sodium cyanide (96-98 percent pure) and 450 cc. of water. The mixture was warmed on a water bath in order to dissolve most of the NaCN; then 1 kg. (8 moles) of benzyl chloride mixed with 1 kg. of 95 percent alcohol was added through the separatory funnel in the course of one hour. The reaction mixture then was heated on a steam bath under a reflux condenser with stirring for four hours, then cooled and filtered with suction to remove most of the NaCl. The filtered salt was washed with four 25 ml. portions of alcohol to remove any benzyl cyanide held mechanically.

The flask then was fitted with a condenser and as much alcohol as possible (about 700 ml.) was removed on a steam bath. The residual liquid was cooled, and the layer of benzyl cyanide separated. This crude benzyl cyanide then was distilled from a Claisen distilling flask under reduced pressure; the water and alcohol distilled first, followed by benzyl cyanide. The crude benzyl cyanide (730 ml.; 88 percent yield) was collected at 135-140 degrees C. (25 mm.).

The benzyl cyanide then was rectified in a Podbieliak Column (8) and the fraction boiling at 127 degrees C. (36 mm.) was collected. This material was used in all of the following preparations except in the first preparation of mandelonitrile acetate in which Eastman White
Lable benzyl cyanide was used.

**Sodium Formate, Sodium Acetate, and Sodium Benzoate**

The salts were available as anhydrous salts of reagent grade quality. Each of these salts was dried prior to use in a reaction for 12 hours at 95 degrees C. in a vacuum oven at four mm. pressure.

**Sodium Propionate**

Propionic acid (81 g., 1.1 moles Eastman White Lable, No. 396) b.p. 137 degrees C. (647.2 mm.) was placed in a 1,000 ml. beaker and 40 g. (1 mole) of sodium hydroxide dissolved in 50 ml. of distilled water was added slowly with stirring. The mixture then was placed on a hot-plate and most of the water removed. It was then allowed to cool, was pulverized with a mortar and pestle, placed on a watch glass, and dried in a vacuum oven at 95 degrees C. (4 mm.) for 12 hours.

**Sodium Butyrate, Sodium Isobutyrate, Sodium Valerate, and Sodium Isovalerate**

These salts were all prepared using the same experimental procedure as that given for sodium propionate. The following quantities of reactants were used:

**Sodium butyrate:**

97 grams (1.1 moles) of butyric acid (Eastman White Lable, No. 60), b.p. 157.5 degrees C. (647.2 mm.).

40 grams (1 mole) of sodium hydroxide in 50 ml. distilled water.

**Sodium isobutyrate:**

97 grams (1.1 moles) of isobutyric acid (Fisher Scientific Co., No. A-80), b.p. 151 degrees C. (647.2 mm.).

40 grams (1 mole) of sodium hydroxide in 50 ml. distilled water.
Sodium valerate:

112 grams (1.1 moles) of valeric acid (Eastman White Label, No. 271), b.p. 182 degrees C. (650.0 mm.).

40 grams (1 mole) of sodium hydroxide in 50 ml. distilled water.

Sodium isovalerate:

112 grams (1.1 moles) of isovaleric acid (Eastman White Label, No. 459), b.p. 172 degrees C. (647.2 mm.).

40 grams (1 mole) of sodium hydroxide in 50 ml. distilled water.

Sodium methylethyl acetate and Sodium trimethyl acetate

These salts were prepared by Fife (4) using the same experimental procedure as that given for sodium propionate. The following quantities of reactants were used:

Sodium methylethyl acetate:

112 grams (1.1 moles) of methylethyl acetic acid, b.p. 115 degrees C. (90 mm.).

40 grams (1 mole) of sodium hydroxide in 50 ml. distilled water.

Sodium trimethyl acetate:

112 grams (1.1 moles) of trimethyl acetic acid, b.p. 75 degrees C. (20 mm.).

40 grams (1 mole) of sodium hydroxide in 50 ml. distilled water.

α-Bromobenzyl Cyanide (13)

The reaction of benzyl cyanide and bromine was carried out in a
three-necked, 200 ml. round-bottomed flask fitted with a Trubore stirrer, an air condenser, a 125 ml. separatory funnel, and a thermometer. Benzyl cyanide (29.25 g.; 0.25 mole) was added to the flask and while being stirred, the reaction mixture was heated to 105-110 degrees C. Bromine (44 g.; 0.275 mole) then was added slowly during a period of one hour. The flask was held at this temperature (105-110 degrees C.) for 15 minutes after the addition of bromine was completed; then, while maintaining the temperature at 105-110 degrees C., dry nitrogen was passed into the flask for 30 minutes. This removed the excess bromine, leaving the dark brown α-bromobenzyl cyanide. The α-bromobenzyl cyanide was used at this point without further purification.

All of the following reactions were carried out in the apparatus used to prepare the α-bromobenzyl cyanide by adding the sodium alkanoates to the α-bromobenzyl cyanide immediately after its preparation.

Mandelonitrile Formate

To 0.25 mole of freshly prepared α-bromobenzyl cyanide, in the apparatus used to prepare the α-bromobenzyl cyanide, was added 18.7 grams (0.275 mole) of sodium formate. The flask then was heated to 130-135 degrees C. and held at this temperature for three hours. The reaction mixture remained dark brown (the color of α-bromobenzyl cyanide used) during the reaction time, and no noticeable change took place. After three hours at 130-135 degrees C., the temperature was allowed to raise to 160-165 degrees C. and was held at this temperature for one hour. The reaction mixture was then poured into an 800 ml. beaker, allowed to cool, and then was extracted with 100 ml. of ether and filtered with suction, using a Buchner funnel. The residue was washed
twice with 75 ml. portions of ether. The ether extracts were combined and the ether removed by evaporation from a steam bath. The residual ester then was distilled under reduced pressure from a Claisen flask. The yield of mandelonitrile formate was 25.5 grams (63.4 percent based on benzyl cyanide used to prepare the α-bromobenzyl cyanide), b.p. 120-130 degrees C. (4 mm.).

Some of the crude ester (nine grams) was further purified by rectification in a Podbielniak Microanalyzer Column, 7 mm., 24" (9). A colorless product was obtained, eight grams, b.p. 125.5-126.5 degrees C. (10 mm.); n_D 1.5160; Sp. gr. 1.1536; M_ν (calc.) 41.56, M_ν (obs.) 42.20. Analysis. Calculated for C_7H_7O_2N: C, 67.1; H, 4.35; N, 8.70. Found: C, 67.5; H, 4.47; N, 8.52.

The reaction also was carried out exactly as above except that a reaction temperature of 140-145 degrees C. was used instead of 130-135 degrees C. The yield obtained using this higher reaction temperature was 21.4 grams (52.6 percent based on the benzyl cyanide used to prepare the α-bromobenzyl cyanide).

Mandelonitrile formate also was prepared by a method in which an excess of α-bromobenzyl cyanide was used. To 0.25 mole of α-bromobenzyl cyanide, prepared as described previously (13), was added 12.8 grams (0.19 mole) of sodium formate. The reaction was conducted exactly as above, using a reaction temperature of 130-135 degrees C. A yield of 18.5 grams (61.3 percent based on the sodium formate used) was obtained.

**Mandelonitrile Acetate**

To a freshly prepared 0.1 mole of α-bromobenzyl cyanide in the apparatus used to prepare the α-bromobenzyl cyanide was added 11.7
grams (0.143 mole) of sodium acetate. The reaction mixture was heated with stirring to 130-135 degrees C. and allowed to remain at that temperature for three hours. The reaction mixture became a bright orange after heating a few minutes. After three hours at this temperature, the temperature of reaction mixture was raised to 160-165 degrees C. and allowed to remain there for 40 minutes. It then was placed in an 800 ml. beaker, allowed to cool, and extracted with 100 ml. of ether. The ether insoluble material was removed by suction filtration and this residue was washed twice with 100 ml. portions of ether. The ether was removed by evaporation from a steam bath and the ester obtained was distilled from a Claisen flask at five mm. pressure. Ten grams (57 percent based on the benzyl cyanide used to prepare the α-bromobenzyl cyanide) of the crude ester was obtained, b.p. 120-130 degrees C. (four mm.).

The crude ester (10 grams) was rectified in a Podbielniak Microanalyzer Column (9) to yield the colorless mandelonitrile acetate, eight grams, b.p. 137-138 degrees C. (11 mm.); \( \nu_20 \lambda = 1.5060; \) Sp. gr. 1.1184; M<sub>r</sub> (calc.) 46.17, M<sub>r</sub> (obs.) 46.53. The boiling point reported for this compound is 137.8 degrees C. (11 mm.) (3).

Mandelonitrile acetate was also prepared by a method in which an excess of α-bromobenzyl cyanide was used.

To 0.25 mole of freshly prepared α-bromobenzyl cyanide was added 15.4 grams (0.19 mole) of sodium acetate. The mixture was heated, extracted, and distilled in the same manner as described above. The yield was 24.3 grams (74 percent based on the sodium acetate used).

**Mandelonitrile Propionate**

To 0.25 mole of the freshly prepared α-bromobenzyl cyanide in the apparatus used to prepare the α-bromobenzyl cyanide was added 18 grams
(0.19 mole) of sodium propionate. The mixture was heated with stirring to 130-135 degrees C. and allowed to remain at that temperature for three hours. The reaction mixture changed to a bright orange color about 10 minutes after the heating was begun, and remained this color until the temperature was raised to 160 degrees C., at which time the color turned brown. After three hours at 130-135 degrees C. the temperature was raised to 160-165 degrees C. and held there for one hour. The reaction mixture was then poured into an 800 ml. beaker, cooled, extracted with 100 ml. of ether, and filtered. The residue was washed with two 75 ml. portions of ether and the ether solutions combined. The ether was removed on a steam bath and the ester distilled from a Claisen flask at reduced pressure. The yield was 25.4 grams (71.6 percent based on the benzyl cyanide used to prepare the \(\alpha\)-bromobenzyl cyanide). Fourteen grams of the crude mandelonitrile propionate were rectified in a Podbielniak Microanalyzer Column (9). Eleven grams of colorless mandelonitrile propionate were obtained, b.p. 141.5-142.5 degrees C. (10 mm.); \(n_D^{20}\) 1.5010; Sp. gr. 1.0865; \(M_r\) (calc.) 50.79, \(M_r\) (obs.) 51.30.

**Analysis.** Calculated for \(C_{11}H_{11}O_2N\): C, 69.8; H, 5.82; N, 7.41; Found: C, 70.2; H, 5.83; N, 7.32.

**Mandelonitrile Butyrate**

To a freshly prepared 0.25 mole of \(\alpha\)-bromobenzyl cyanide in the apparatus used to prepare the \(\alpha\)-bromobenzyl cyanide was added 30.3 grams (0.275 mole) of sodium butyrate. The temperature of the reaction mixture was raised to 130-135 degrees C. and held there. After about five minutes at this temperature the reaction mixture became extremely viscous and impossible to stir; therefore 30 ml. of dioxane was added. The reaction
mixture became somewhat less viscous and was maintained at a temperature
of 110-120 degrees C. with stirring for one hour. The temperature then
was raised to 130 degrees C. (some dioxane being lost through the air
condenser) and after about two hours at 130-135 degrees C., the reaction
mixture became fluid. It was heated one more hour at 130-135 degrees C.
after which the temperature was raised to 160-165 degrees C. (dioxane
being lost through the air condenser) and held there for 30 minutes.
The ester was poured into an 800 ml. beaker, extracted with 100 ml. of
ether, filtered, and the residue washed with two 75 ml. portions of
ether. The ether solutions were combined and the ether evaporated on
a steam bath. The ester obtained was distilled at reduced pressure.
A yield of 41.6 grams (82.1 percent based on the benzyl cyanide used
to prepare α-bromobenzyl cyanide) of mandelonitrile butyrate was ob-
tained, b.p. 130-140 degrees C. (four mm.).

Thirty-two grams of this crude ester were purified by rectification
in a Podbielniak Microanalyzer Column (9). Twenty-seven grams of color-
less mandelonitrile butyrate were obtained, b.p. 150-151 degrees C.
(10 mm.); nD 1.4964; Sp. gr. 20 1.0610; M_r (calc.) 55.41, M_r (obs.)
55.99.

Analysis. Calculated for C_{12}H_{13}O_2N: C, 70.9; H, 6.40; N, 6.90.
Found: C, 70.6; H, 6.42; N, 6.82.

The mandelonitrile butyrate also was prepared using an excess of
α-bromobenzyl cyanide. To 0.25 mole of α-bromobenzyl cyanide was
added 20.6 grams (0.19 mole) of sodium butyrate. The reaction mixture
was heated three hours at 130-135 degrees C. and one hour at 160-165
degrees C. The reaction mixture did not become noticeably viscous at
any time. The ester was extracted with ether and distilled as above. A yield of 30.8 grams (80.9 percent based on sodium butyrate) of mandelonitrile butyrate was obtained.

A third method used in preparing mandelonitrile butyrate was to use an excess of the sodium salt as in the first preparation but to add it in two portions. This method permits the reaction to take place without a diluent.

To 0.25 mole of \(\alpha\)-bromobenzyl cyanide was added 15 grams of sodium butyrate. The reaction mixture was heated at 130-135 degrees C. with stirring for one-half hour; then the remaining 15.3 grams (making a total of 0.275 mole) was added. The mixture became somewhat viscous but was easily stirred. After being heated an additional three hours at 130-135 degrees C. the temperature was raised to 160-165 degrees C. and maintained there for one hour. The reaction mixture was extracted and distilled as above. A yield of 39 grams (76.8 percent) of mandelonitrile butyrate was obtained.

**Mandelonitrile Isobutyrate**

This ester was prepared by using an excess of sodium isobutyrate. To 0.25 mole of freshly prepared \(\alpha\)-bromobenzyl cyanide in the apparatus used to prepare the \(\alpha\)-bromobenzyl cyanide was added 15 grams of sodium isobutyrate. The reaction mixture immediately became very thick and difficult to stir; therefore 40 ml. of dioxane was added as a diluent. The temperature was raised slowly to 130-135 degrees C. After remaining at this temperature for one hour the remaining 13.5 grams (making a total of 0.26 mole) of sodium isobutyrate was added. The reaction mixture was heated at 130-135 degrees C. for an additional three hours, then at 160-165 degrees C. for one hour. The resulting
ester was then poured into an 800 ml. beaker and extracted with 100 ml. of ether, filtered, and the residue washed with two 75 ml. portions of ether. The ether solutions were combined, the ether removed on a steam bath, and the ester distilled at reduced pressure. A yield of 38.4 grams (77.6 percent based on the benzyl cyanide used to prepare the α-bromobenzyl cyanide) of mandelonitrile isobutyrate was obtained, b.p. 120-130 degrees C. (four mm.).

Five grams of this ester were further purified by rectification in a Podbielniak Microanalyzer Column (9). Four grams of colorless mandelonitrile isobutyrate were obtained, b.p. 139-140 degrees C. (10 mm.); n_D^20 1.4916; Sp. gr. 20^20 1.0475; M_r (calc.) 55.41, M_r (obs.) 56.25.

Analysis. Calculated for C_{12}H_{13}O_2N: C, 70.9; H, 6.40; N, 6.90. Found: C, 71.1; H, 6.45; N, 6.88.

Mandelonitrile Valerate

To 0.25 mole of α-bromobenzyl cyanide in the apparatus used to prepare the α-bromobenzyl cyanide was added 32 grams (0.26 mole) of sodium valerate. The reaction mixture immediately became very thick and impossible to stir; therefore 30 ml. of dioxane was added to make stirring possible. The temperature was raised slowly to 130-135 degrees C. and allowed to remain there. After two hours at this temperature the reaction mixture became fluid and was easily stirred. It was heated one hour longer at 130-135 degrees C.; then it was heated at 160-165 degrees C. for one hour and poured into an 800 ml. beaker to cool. The ester was extracted with 100 ml. of ether, filtered, and the residue washed twice with two 75 ml. portions of ether. The ether solutions were combined and the ether evaporated on a steam bath. The resulting crude
ester was distilled from a Claisen flask at reduced pressure. A yield of 44.1 grams (81.3 percent) was obtained, b.p. 140-150 degrees C. (four mm.). Fourteen grams of the ester were purified by rectification in a Podbielniak Microanalyzer Column (9). Eleven grams of colorless mandelonic nitrile valerate were obtained, b.p. 159-160 degrees C. (10 mm.); \( n^2_2 \) 1.4943; Sp. gr. 20 1.0401; \( M_T \) (calc.) 60.03, \( M_T \) (obs.) 60.84.

**Analysis.** Calculated for \( C_{13}H_{15}O_2N \): C, 71.9; H, 6.91; N, 6.45. Found: C, 71.9; H, 7.03; N, 6.25.

**Mandelonic Nitrile Isovalerate**

To 0.25 mole of freshly prepared \( \alpha \)-bromobenzyl cyanide in the apparatus used to prepare the \( \alpha \)-bromobenzyl cyanide was added 10 grams of sodium isovalerate. This was allowed to react at 130-135 degrees C. for one hour; then 10 more grams of sodium isovalerate were added. After one-half hour the remaining 12 grams of salt were added and the reaction mixture heated at 130-135 degrees C. for three hours. The reaction mixture became slightly thick after the first 10 grams of salt were added but remained thin after the addition of the last two portions. After being heated at 160-165 degrees C. for one hour the reaction mixture was poured into a 800 ml. beaker. The ester was extracted with ether and distilled under reduced pressure from a Claisen flask. A yield of 43.7 grams (80.5 percent) was obtained, b.p. 135-145 degrees C. (six mm.).

Twenty-six grams of this ester were purified by rectification in a Podbielniak Microanalyzer Column (9). Twenty-one grams of colorless mandelonic nitrile isovalerate were obtained, b.p. 148-149 degrees C. (10 mm.); \( n^2_2 \) 1.4908; Sp. gr. 20 1.0345; \( M_T \) (calc.) 60.03, \( M_T \) (obs.) 60.80.

**Analysis.** Calculated for \( C_{13}H_{15}O_2N \): C, 71.9; H, 6.91; N, 6.45. Found: C, 71.7; H, 6.92; N, 6.35.
Mandelonitrile Methylethyl Acetate

To 0.25 mole of α-bromobenzyl cyanide in the apparatus used to prepare the α-bromobenzyl cyanide was added 10 grams of sodium methylethyl acetate. This reaction mixture became rather viscous at first but soon broke down on vigorous stirring. After the first 10 grams had been allowed to react for 30 minutes at 130-135 degrees C., 10 grams more of salt was added and the mixture allowed to react for another 30 minutes; the remaining 12 grams (making a total of 0.26 mole) of sodium methylethyl acetate then was added and the flask heated at 130-135 degrees C. for three hours. The temperature was then allowed to raise to 160-165 degrees C. and was held there for one hour. The crude ester was poured into an 800 ml. beaker, extracted with 100 ml. of ether, and filtered. The residue was washed with two 75 ml. portions of ether and the ether solutions combined. The ether then was removed on a steam bath and the ester distilled under reduced pressure from a Claisen flask. A yield of 41.5 grams (76.5 percent) was obtained, b.p. 128-138 degrees C. (four mm.).

Twenty-eight grams of this ester were further purified by rectification in a Podbielniak Microanalyzer Column (9). Twenty-five grams of mandelonitrile methylethyl acetate were obtained, b.p. 149-150 degrees C. (10 mm.); n^D_20 1.4910; Sp. gr. 20 1.0368; M_r (calc.) 60.03, M_r (obs.) 60.69.

Analysis. Calculated for C_{13}H_{15}O,N: C, 71.9; H, 6.91; N, 6.45. Found: C, 71.6; H, 7.05; N, 6.43.

Mandelonitrile Trimethyl Acetate

The procedure used in preparing this compound was exactly the same as that used in preparing the methylethyl acetate. A yield of 37.9
grams (74.5 percent) was obtained, b.p. 120-130 degrees C.

Twenty-four grams of this ester were purified by rectification in a Podbielniak Microanalyser Column (9). Twenty grams of colorless mandelonitrile trimethyl acetate were obtained, b.p. 136-137 degrees C. (10 mm.); n_D^20 1.4862; Sp. gr. 20 1.0257; M_r (calc.) 60.03, M_r (obs.) 60.84.

**Analysis.** Calculated for C_13H_15O_2N: C, 71.9; H, 6.91; N, 6.45.

**Found:** C, 72.1; H, 6.89; N, 6.41.

**Mandelonitrile Benzoate**

This ester was prepared using an excess of sodium benzoate, 0.26 mole of sodium benzoate to 0.25 mole α-bromobenzyl cyanide.

To 0.25 mole of α-bromobenzyl cyanide in the apparatus used to prepare the α-bromobenzyl cyanide was added 12 grams of sodium benzoate. This was allowed to react 30 minutes at 140-145 degrees C. The solution became somewhat viscous at first but became very fluid again after about 15 minutes. After the first 12 grams of sodium benzoate had been allowed to react for 30 minutes, 12 more grams of sodium benzoate were added and allowed to react for another 30 minutes at 140-145 degrees C. The remaining 13 grams of salt were then added and the reaction mixture heated to 140-145 degrees C. for six hours. After four hours the viscosity of the reaction mixture decreased considerably, but it never became as fluid as the other esters. After heating six hours at 140-145 degrees C. the reaction mixture was heated at 165-170 degrees C. for one hour, then poured into an 800 ml. beaker, extracted with 100 ml. of ether, and filtered. The residue was washed with two 75 ml. portions of ether and the ether solutions combined. The ether then was
removed on a steam bath and the ester distilled under reduced pressure from a Claisen flask. A yellow solid was obtained. Boiling range was 130–165 degrees C. (four mm.). This ester was purified by two recrystallizations from 300 ml. of 95 percent ethanol. A yield of 33 grams (56.6 percent) of white crystalline mandelonitrile benzoate was obtained, m.p. 59 degrees C. Further recrystallization did not raise the melting point.
<table>
<thead>
<tr>
<th>Ester of Mandelonitrile</th>
<th>Reaction time Hours at 130-135 degrees C.</th>
<th>Yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formate</td>
<td>3</td>
<td>61.3*</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>63.4</td>
</tr>
<tr>
<td></td>
<td>3***</td>
<td>52.6</td>
</tr>
<tr>
<td>Acetate</td>
<td>3</td>
<td>57.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>74.0*</td>
</tr>
<tr>
<td>Propionate</td>
<td>3</td>
<td>71.6*</td>
</tr>
<tr>
<td>Butyrate</td>
<td>3</td>
<td>80.9*</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>82.1**</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>76.8</td>
</tr>
<tr>
<td>Isobutyrate</td>
<td>3</td>
<td>77.6**</td>
</tr>
<tr>
<td>Valerate</td>
<td>3</td>
<td>81.3**</td>
</tr>
<tr>
<td>Isovalerate</td>
<td>3</td>
<td>80.5</td>
</tr>
<tr>
<td>Methylthyl acetate</td>
<td>3</td>
<td>76.5</td>
</tr>
<tr>
<td>Trimethyl acetate</td>
<td>3</td>
<td>74.5</td>
</tr>
<tr>
<td>Benzoate</td>
<td>6***</td>
<td>56.6</td>
</tr>
</tbody>
</table>

With those not starred, an excess of the sodium salt was used and no solvent.

* An excess of α-bromobenzyl cyanide was used.

** An excess of the sodium salt was used and dioxane was used as a diluent to permit satisfactory stirring.

*** Reaction temperature was 140-145 degrees C.
<table>
<thead>
<tr>
<th>Ester of Mandelonitrile</th>
<th>b.p. degrees C. 10 mm.</th>
<th>( n^D )</th>
<th>Sp. Gr. 20</th>
<th>( M_r ) (Calc.)</th>
<th>( M_r ) (obs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formate</td>
<td>125.5-126.5</td>
<td>1.5160</td>
<td>1.1536</td>
<td>41.56</td>
<td>42.20</td>
</tr>
<tr>
<td>Acetate</td>
<td>137-138*</td>
<td>1.5060</td>
<td>1.1184</td>
<td>46.17</td>
<td>46.53</td>
</tr>
<tr>
<td>Propionate</td>
<td>141.5-142.5</td>
<td>1.5010</td>
<td>1.0865</td>
<td>50.79</td>
<td>51.30</td>
</tr>
<tr>
<td>Butanoate</td>
<td>150-151</td>
<td>1.4964</td>
<td>1.0610</td>
<td>55.41</td>
<td>55.99</td>
</tr>
<tr>
<td>Isobutyrate</td>
<td>139-140</td>
<td>1.4916</td>
<td>1.0475</td>
<td>55.41</td>
<td>56.25</td>
</tr>
<tr>
<td>Valerate</td>
<td>159-160</td>
<td>1.4943</td>
<td>1.0401</td>
<td>60.03</td>
<td>60.84</td>
</tr>
<tr>
<td>Isovalerate</td>
<td>148-149</td>
<td>1.4908</td>
<td>1.0345</td>
<td>60.03</td>
<td>60.80</td>
</tr>
<tr>
<td>Methylethyl acetate</td>
<td>149-150</td>
<td>1.4910</td>
<td>1.0368</td>
<td>60.03</td>
<td>60.69</td>
</tr>
<tr>
<td>Trimethyl acetate</td>
<td>136-137</td>
<td>1.4862</td>
<td>1.0257</td>
<td>60.03</td>
<td>60.84</td>
</tr>
</tbody>
</table>

*Rectified at 11 mm.
Table 3. Combustion analysis of new compounds

<table>
<thead>
<tr>
<th>Ester of Mandelonitrile</th>
<th>Wt. Sample</th>
<th>Wt. H₂O</th>
<th>% H</th>
<th>Calc. % H</th>
<th>Wt. CO₂</th>
<th>% C</th>
<th>Calc. % C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formate</td>
<td>0.2387</td>
<td>0.0953</td>
<td>4.47</td>
<td>4.35</td>
<td>0.5893</td>
<td>67.5</td>
<td>67.1</td>
</tr>
<tr>
<td>Propionate</td>
<td>0.2253</td>
<td>0.1172</td>
<td>5.83</td>
<td>5.82</td>
<td>0.5802</td>
<td>70.2</td>
<td>69.8</td>
</tr>
<tr>
<td>Butyrate</td>
<td>0.2147</td>
<td>0.1231</td>
<td>6.42</td>
<td>6.40</td>
<td>0.5557</td>
<td>70.6</td>
<td>70.9</td>
</tr>
<tr>
<td>Isobutyrate</td>
<td>0.2091</td>
<td>0.1203</td>
<td>6.45</td>
<td>6.40</td>
<td>0.5449</td>
<td>71.1</td>
<td>70.9</td>
</tr>
<tr>
<td>Valerate</td>
<td>0.2149</td>
<td>0.1364</td>
<td>7.03</td>
<td>6.91</td>
<td>0.5657</td>
<td>71.9</td>
<td>71.9</td>
</tr>
<tr>
<td>Isovalerate</td>
<td>0.2162</td>
<td>0.1336</td>
<td>6.92</td>
<td>6.91</td>
<td>0.5679</td>
<td>71.7</td>
<td>71.9</td>
</tr>
<tr>
<td>Methylethyl acetate</td>
<td>0.2177</td>
<td>0.1371</td>
<td>7.05</td>
<td>6.91</td>
<td>0.5714</td>
<td>71.6</td>
<td>71.9</td>
</tr>
<tr>
<td>Trimethyl acetate</td>
<td>0.2105</td>
<td>0.1296</td>
<td>6.89</td>
<td>6.91</td>
<td>0.5558</td>
<td>72.1</td>
<td>71.9</td>
</tr>
</tbody>
</table>
Table 4. Nitrogen analyses of new compounds by Kjeldahl method

<table>
<thead>
<tr>
<th>Ester of Mandelonitrile</th>
<th>Wt. Sample</th>
<th>ml. H₂SO₄ 0.1181 N</th>
<th>ml. NaOH 0.1213 N</th>
<th>% N found</th>
<th>% N calc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formate</td>
<td>0.7606</td>
<td>50</td>
<td>10.53</td>
<td>8.52</td>
<td>8.70</td>
</tr>
<tr>
<td>Propionate</td>
<td>0.9567</td>
<td>50</td>
<td>7.53</td>
<td>7.32</td>
<td>7.41</td>
</tr>
<tr>
<td>Butyrate</td>
<td>0.9635</td>
<td>50</td>
<td>10.02</td>
<td>6.82</td>
<td>6.90</td>
</tr>
<tr>
<td>Isobutyrate</td>
<td>0.7367</td>
<td>50</td>
<td>18.92</td>
<td>6.88</td>
<td>6.90</td>
</tr>
<tr>
<td>Valerate</td>
<td>0.5695</td>
<td>50</td>
<td>27.75</td>
<td>6.25</td>
<td>6.45</td>
</tr>
<tr>
<td>Isovalerate</td>
<td>1.3823</td>
<td>75</td>
<td>21.34</td>
<td>6.35</td>
<td>6.45</td>
</tr>
<tr>
<td>Methylethyl acetate</td>
<td>0.8831</td>
<td>50</td>
<td>15.31</td>
<td>6.43</td>
<td>6.45</td>
</tr>
<tr>
<td>Trimethyl acetate</td>
<td>0.9679</td>
<td>30*</td>
<td>29.94**</td>
<td>6.41</td>
<td>6.45</td>
</tr>
</tbody>
</table>

*Acid was 0.2710 N HCl.
**Base was 0.1237 N NaOH.
SUMMARY AND CONCLUSIONS

1. α-Bromobenzyl cyanide was found to react with the sodium salts of the following acids: formic, acetic, propionic, butyric, isobutyric, valeric, isovaleric, methylethyl acetic, trimethyl acetic, and benzoic.

2. The structures of the mandelonitrile acetate and the benzoate were established by comparing the physical properties of the benzoate and acetate with the physical properties of these compounds which were recorded in the literature. The composition of the other mandelonitrile alkanoates was established by elementary analyses of the esters.

3. The densities, refractive indices, and boiling points (melting point for the benzoate) were determined for the esters.

4. It was found that as the carbon chain of the acid groups increased in length or became branched, the reaction mixture would become thick in the reaction flask a few minutes after the reaction was started. This is thought to be due to the formation of a complex intermediate, and therefore an indication of the reactivity of the sodium alkanoate; however, no definite evidence to substantiate this idea is available from this research.

5. Research should be continued along this line with various other compounds containing active halogens.

The reaction of sodium alkanoates might well be tried with such compounds as diphenyl chloromethane, 1,3-diketo-2-chloro compounds, or any of a number of compounds which have a halogen atom attached to a carbon atom which, in turn, is attached to one or more negative groups.
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