black cloth. Solutions of potassium nitrate were made up in a similar manner.

Apparatus and Procedure.—All distributions were carried out in a water-bath at 25 ± 0.01°. Iodine flasks of 250-ml. capacity, equipped with mercury seal type stirrers but using glycerol as a seal, were used. A piece of glass tubing sealed to the end of a glass rod effectively stirred the layers, which appeared in the form of a fine emulsion during the stirring. Several runs in which the flasks were flushed with nitrogen before starting the experiment showed no difference from those carried out in air. Twenty ml. of saturated isooctane solution containing approximately 0.3 g. of ester was added to 20 ml. of the aqueous methanol solution saturated with isoöctane. Stirring was continued for 30 minutes. Stirring for longer periods gave the same results. Usually the layers separated completely in less than 30 minutes. A 10-ml. sample of upper layer was withdrawn for analysis with the aid of a Luer syringe attached to a pipet by means of rubber tubing.

Analytical Procedure.—The customary procedure using Wijs solution[4] proved satisfactory for the analysis of the upper layer provided that the sample was allowed to stand one hour in contact with reagent. In each analysis 10 ml. of Wijs solution was added to 10 ml. of the upper layer from a distribution experiment. A blank was run on 10 ml. of isoöctane saturated with the appropriate methanol solution.

Results and Discussion

The notation and assumptions regarding activities of previous workers[2,3] were used with the substitution of isoöctane for carbon tetrachloride and aqueous methanol for water. The argentation constant, K_0, has been expressed previously[2] by equation (1).

$$K_0 = \frac{(\mathrm{Bt})_{x\mathrm{N\ AgNO_3}} - (\mathrm{B})_{\mathrm{iso}}/K_D}{(\mathrm{B})_{\mathrm{iso}}[(\mathrm{Agt})_{x\mathrm{N\ AgNO_3}} - ((\mathrm{Bt})_{x\mathrm{N\ AgNO_3}} - (\mathrm{B})_{\mathrm{iso}}/K_D)]} \quad (1)$$

If K_D is very large the term $(\mathrm{B})_{\mathrm{iso}}/K_D$ may be neglected in Eq. (1). However, in most of our work this approximation could not be used.

If one can alter K_D without materially altering K_E, the effect will be reflected by a corresponding change in K_0. One way to alter K_D is to change the ratio of water to methanol in the aqueous phase. Another way is to change the ionic strength of the phase containing silver nitrate.

From the above discussion it is apparent that K_E is to be preferred to K_0 as a measure of the relative coördination tendencies of double bonds in different types of olefins, but when the substances being compared have essentially the same distribution constants, as for example *cis*- and *trans*-isomers, K_0 would serve as an adequate measure of these tendencies under the same conditions.

The constants obtained for the isomeric methyl oleate and methyl elaidate in several solvent combinations are shown in Table I. The striking differences in argentation constants for the two isomers are in close agreement, even to order of magnitude, with previous observations.[3] It appears from the limited data in Table I that K_E is relatively unaffected by changes in methanol concentration and that K_0 is inversely proportional to K_D but this is not certain. Experimental error in the measurements, together with possible large changes in activity coefficient due to large changes in silver ion concentrations, obscure any accurate interpretation of the differences in equilibrium constants.

By use of increasing concentrations of methanol it has been shown that relatively large amounts of methyl oleate and methyl elaidate can be removed from isoöctane in a single extraction. The fraction of olefin removed in a single extraction is shown in equation (2) which was checked experimentally.

$$F = \frac{(\mathrm{Bt})_{x\mathrm{N\ AgNO_3}}}{(\mathrm{B})_T} = \frac{K_0K_D(\mathrm{Agt}) + K_0(\mathrm{B})_T + 1}{K_0K_D(\mathrm{Agt}) + K_0K_D(\mathrm{B})_T + 2K_0(\mathrm{B})_T + K_D + 1} \quad (2)$$

In order to attain anything like complete separation a number of successive extractions would be required. The technique of countercurrent distribution, as employed by Craig,[5,6] or paper chromatography could be easily adapted to the solvent combinations used in the present work. In a Craig apparatus the number of transfers, n, required to obtain a desired separation can be calculated by approximate relations derived by Nichols.[7] Using the argentation constants for methyl oleate and methyl elaidate for 90% methanol and 0.2 M silver nitrate, calculations show that approximately 300 transfers would be required for reasonably complete separation.

TABLE I

ARGENTATION CONSTANTS AND DISTRIBUTION RATIO FOR THE DISTRIBUTION OF METHYL OLEATE AND METHYL ELAIDATE BETWEEN ISOÖCTANE AND AQUEOUS METHANOL[a]

Concn. of methanol, %	Concn. of $AgNO_3$, N	Methyl oleate[d] K_D	Methyl oleate[d] K_0	Methyl oleate[d] K_E	Methyl elaidate[d] K_D	Methyl elaidate[d] K_0	Methyl elaidate[d] K_E
60	1.0	[b]	0.02	...	..	0.02	...
90	0.2	[b]	.46[c]	...	..	.17	...
95	.16	10.5	.79	8.2	10.1	.29	2.9
100	.05	4.2	2.02	8.4	3.9	.81	3.1

[a] Except where noted the average value for two runs is recorded. [b] Too high for a reasonable estimate by the analytical method used. [c] Average value for three runs. [d] Initial concentration in isoöctane layer is approx. 0.05 molar.

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Benzyl Esters of Amino Acids[1]

BY HERBERT K. MILLER[2] AND HEINRICH WAELSCH

The synthesis of carboxyl-substituted peptides is greatly facilitated by the use of benzyl esters of amino acids instead of the commonly employed ethyl esters since the benzyl group can be removed by hydrogenation with palladium catalyst under the same conditions as used for the removal of the carbobenzoxy group thus avoiding the need for saponification.[3]

(1) This report is in part from a dissertation submitted by Herbert K. Miller in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the Faculty of Pure Science, Columbia University.

(2) Atomic Energy Commission Predoctoral Fellow, 1949–1950.

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Benzyl esters of amino acids have been prepared by the coupling of amino acid chloride hydrochlorides with benzyl alcohol[4,5,6] and through the use of benzyl alcohol saturated with dry hydrogen chloride.[7] Bergmann, *et al.*,[8] have coupled N-carbonic acid anhydrides of amino acids with benzyl alcohol. These methods are laborious and tend to low yields. We have found that esterification takes place in good yield when the amino acid is rendered soluble in benzyl alcohol by the formation of a benzenesulfonic acid salt. The preparation of the benzyl esters of glycine, DL-phenylalanine and L-leucine is reported.

Experimental

Glycine Benzyl Ester.—A solution of 75 g. (1 mole) of glycine and 174 g. (1.1 moles) of benzenesulfonic acid dissolved in 500 g. of benzyl alcohol by gentle heating was distilled *in vacuo* with a bath temperature not exceeding 130°. After most of the benzyl alcohol was removed, the hot mass was poured into a mortar and a half-liter of ether was added as soon as it had cooled sufficiently to prevent the ether from boiling too vigorously. The mass was then rubbed until crystallization ensued, washed with ether and air-dried. The impure material (314 g.) was dissolved in 500 g. of benzyl alcohol, an additional 5 g. of benzenesulfonic acid was added and the benzyl alcohol was again removed *in vacuo* as described above. The crystallization (as above) yielded 323 g. (100%). This salt may have as impurity a small amount of unreacted glycine benzenesulfonate. For purification the salt may be converted to the hydrochloride.

To a suspension of 65 g. (0.2 mole) of the glycine benzyl ester benzenesulfonate in 300 ml. of chloroform at 0–5°, 20 g. (0.2 mole) of triethylamine was added over a period of ten minutes. After addition of one liter of absolute ether the mixture was allowed to stand for ten minutes after which time the precipitated triethylammonium benzenesulfonate was filtered off and the ethereal solution concentrated *in vacuo* with rigid exclusion of moisture. The remaining pale yellow oil weighed 23–26 g. (70–80%).

Glycine Benzyl Ester Hydrochloride.—An ethereal solution of glycine benzyl ester was treated with dry hydrogen chloride until no further precipitation of the hydrochloride occurred. The hydrochloride crystallized out in about 70% yield. It may be stored indefinitely and can be further purified by recrystallization from hot benzyl alcohol or ethylene glycol monomethyl ether acetate (methyl cellosolve acetate), m.p. 131–132°.[8]

Anal. Calcd. for $C_9H_{12}O_2NCl$ (201.7): Cl, 17.58. Found: Cl, 17.56.

The hydrochloride is readily converted to the free base by neutralization with triethylamine in the same manner as described for the glycine benzyl ester benzenesulfonate.

DL-Phenylalanine Benzyl Ester Hydrochloride.—To 8.7 g. (0.055 mole) of benzenesulfonic acid dissolved in 100 g. of warm benzyl alcohol 8.25 g. (0.05 mole) of DL-phenylalanine was added and esterification was carried out exactly as in the case of glycine ester. After the second removal of benzyl alcohol about 20 g. (97%) of the crude phenylalanine benzyl ester benzenesulfonate was obtained. This product was converted to the hydrochloride from the free base obtained by the action of triethylamine on the benzenesulfonate as in the method for glycine benzyl ester hydrochloride described above. The yield of phenylalanine benzyl ester hydrochloride was 10.9 g. (75%). It was recrystallized from hot benzyl alcohol, m.p. 196°.

Anal. Calcd. for $C_{16}H_{18}O_2NCl$ (291.8): Cl, 12.15. Found: Cl, 12.11.

L-Leucine Benzyl Ester Hydrochloride.—To 34.8 g. (0.22 mole) of benzenesulfonic acid dissolved in 100 ml. of warm benzyl alcohol 26.2 g. (0.2 mole) of L-leucine was added and esterification was carried out exactly as in the case of glycine ester. After the second removal of benzyl alcohol about 72 g. (95%) of the crude leucine benzyl ester benzenesulfonate was obtained. This product was suspended in 200 ml. of chloroform and 26.6 ml. (0.19 mole) of triethylamine was added over a period of 15 minutes while the suspension was continually stirred in an ice-bath. To the resulting solution 400 ml. of anhydrous ether was added and the precipitated triethylammonium benzenesulfonate was removed by filtration. The supernatant solution was saturated with dry HCl and taken to dryness *in vacuo*. The residue was dissolved in 25 ml. of hot chloroform and 350 ml. of hot cyclohexane was added. After 16 hours at 0–5°, the crystalline product was collected, washed with cyclohexane and dried *in vacuo* (yield 38 g). An additional yield of 7 g. was obtained from the mother liquor by the addition of another volume of cyclohexane (88% based on the amount of leucine used). It was recrystallized from chloroform–cyclohexane, m.p. 129°.

Anal. Calcd. for $C_{13}H_{20}O_2NCl$ (257.6): Cl, 13.76. Found: Cl, 13.80; $[\alpha]^{30}D$ −8° (2% in 0.1 *N* HCl).

The optical homogeneity of the ester was demonstrated by the optical rotation of the L-leucine derived from it by hydrogenation; $[\alpha]^{30}D$ +15.5° (2% in 6.09 *N* HCl) *cf.* Dunn, *et al.*[9] No racemization occurred, therefore, during the esterification.

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Tris-(β-chloroallyl) Phosphate[1]

BY ROBERT M. REINHARDT

Tris-(β-chloroallyl) phosphate has been prepared by a method analogous to that of Whitehill and Barker[2] for the preparation of triallyl phosphate.

To a mixture of 240 g. (2.59 mole) of β-chloroallyl alcohol,[3] 240 g. of toluene and 400 g. of anhydrous pyridine in a 2-liter, 3-necked flask equipped with thermometer well, mechanical stirrer, and dropping funnel, was added 111 g. (0.72 mole) of phosphorus oxychloride in 111 g. of toluene, dropwise, and with stirring. The reaction temperature was maintained at −35 to −40° throughout the addition by immersion of the flask in an acetone–Dry Ice-bath. With rapid stirring the addition was complete in approximately 1 hour. The mixture was maintained at −40° for an additional hour; then allowed to warm to room temperature. One liter of distilled water was added to dissolve the pyridine hydrochloride formed in the reaction. The toluene layer was separated and washed successively, in a separatory funnel, with 600 ml. of water, 600 ml. of 15% sodium carbonate solution and 600 ml. of water. The toluene layer was dried over sodium carbonate and stripped of solvent and of unreacted β-chloroallyl alcohol under vacuum (18 mm.) at a temperature below 50° leaving 167 g. of crude product (71.8%).

Vacuum distillation of 21.4 g. of the crude product, with 0.3 g. of hydroquinone and 3 g. of sodium carbonate (to prevent explosion),[4,5] yielded 14.6 g. of tris-(β-chloroallyl)

(1) Contribution from the Southern Regional Research Laboratory, one of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture. Article not copyrighted.

(2) L. N. Whitehill and R. S. Barker (to Shell Development Co.), U. S. Patent 2,394,829 (1946).

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