224. *Experiments on the Interaction of Hydroxy Compounds and Phosphorus and Thionyl Halides in the Absence and in the Presence of Tertiary Bases. Part IV.*

By W. Gerrard and M. J. Richmond.

The nature and sequence of the reactions which occur during the interaction of phosphorus halides and ethyl (+)lactate are defined in some detail. The (+)chlorophosphites, PCl_2OR, $PCl(OR)_2$, but no chloride, RCl, were formed by addition of (+)lactate to excess trichloride, whereas with reversed order of mixing, trichloride (0·33 mol.) gave the (−)chloride, RCl, and the (+)hydrogen phosphite, $P(OR)_2OH$, hydrogen chloride being the probable cause of chloride, RCl, formation. Results with phosphorus tribromide, though less decisive, indicated analogy in types; but the bromophosphites could not be isolated.

With the trihalide (0·33 mol.) and (+)lactate (1 mol.), pyridine, quinoline, and dimethylaniline (1 mol.) behaved similarly, the products being the phosphite, $P(OR)_3$, and the hydrohalide of the base. No chloride, RCl, was produced by the further addition of trichloride followed by heating, neither did the chlorophosphites [contrast the chlorosulphinate (Gerrard, J., 1936, 688)] react with the free bases below 100°. Further addition of tribromide led to a low yield of bromide, RBr, when pyridine was the base, but high yields of almost completely racemised bromide when quinoline and dimethylaniline were used.

Other differences in behaviour of the individual tertiary bases are revealed by corresponding experiments with phosphorus oxychloride.

In certain experiments, ethyl (+)lactate behaved similarly to (+)β-octanol, in others, similarly to ethyl (+)mandelate; the reaction mechanisms may be explained in terms of end-on and broadside collisions (Parts I, II, III, J., 1944, 85; this vol., p. 106, and preceding paper).

The interactions of ethyl (+)lactate and the trichloride, tribromide, and oxychloride of phosphorus in the absence and in the presence of the tertiary bases, pyridine, quinoline and dimethylaniline severally, have been studied so that the results may be correlated with those obtained for (+)β-octanol, (+)phenylmethylcarbinol, and ethyl (+)mandelate (Parts I, II, III, *locc. cit.*).

It is evident from the work of Kenyon, Phillips, and Turley (J., 1925, **127**, 399), Gerrard, Kenyon, and Phillips (J., 1937, 153), and Cowdrey, Hughes, and Ingold (J., 1937, 1208) that when ethyl (+)lactate is converted into an ethyl (−)α-halogenopropionate, an inversion of configuration occurs.

Addition of ethyl (+)lactate to the trichloride (2 mols.) led to the formation of *(+)α-carbethoxyethyloxyphosphorus dichloride*, PCl_2OR, $\alpha_D^{16^\circ}$ +201·3° (l = 10 cm.) and *(+)di-α-carbethoxyethyloxyphosphorus monochloride*, $PCl(OR)_2$, $\alpha_D^{16^\circ}$ +160·4° (l = 10 cm.); but no ethyl α-chloropropionate was formed. These chlorophosphites are stable below 200°; the dichloride indeed could be distilled at ordinary pressure. Addition of the trichloride (0·33 mol.) to the (+)lactate gave rise to a 25% yield of (−)α-chloropropionate, the other main product being *(+)di-α-carbethoxyethyl hydrogen phosphite*, $P(OR)_2{\cdot}OH$, $\alpha_D^{16^\circ}$ +79·4° (l = 10 cm.). Therefore the behaviour of ethyl (+)lactate is similar to that of (+)β-octanol (Part I, *loc. cit.*). In a similar way it may be concluded that the chlorophosphites and phosphites are produced by a broadside approach of the reacting molecules; and whereas the end-on and the broadside attack of hydrogen chloride (formed concurrently) on the chlorophosphites is ineffective, the end-on attack of hydrogen chloride on the phosphite, $P(OR)_3 + HCl \longrightarrow RCl + P(OR)_2OH$, appears to be responsible for the formation of the chloride, RCl.

Reference may here be made to the summary in Houben–Weyl (1923, **3**, (2), 15) in which it is stated that primary alcohols give with phosphorus trichloride the dichlorophosphite, whilst secondary alcohols give in the main the unsaturated hydrocarbon, and tertiary alcohols give the chloride, RCl. This summary, dissociated from conditional details, is without meaning, and should therefore be discarded. At least one investigator has used it as a basis for argument; Wagner-Jauregg (*Helv. Chim. Acta*, 1929, **12**, 61), referring to this summary, drew a distinction between the behaviour of phosphorus oxychloride and that of the trichloride on the grounds that the behaviour of the oxychloride cannot be generalised in this way.

From addition of ethyl (+)lactate to phosphorus tribromide (2 mols.) ethyl (−)α-bromopropionate, $\alpha_D^{16^\circ}$ −42·1° (l = 10 cm.), was obtained in 26% yield; this distinction from the behaviour of the trichloride is probably due to the interaction of the hydrogen bromide and the bromophosphites. The yield of bromide, RBr, is reduced to less than 5% by the passage of carbon dioxide through the tribromide, a procedure effecting the removal of hydrogen bromide produced in the primary reaction, $PBr_3 + ROH \longrightarrow PBr_2OR + HBr$. The bromophosphites, PBr_2OR and $PBr(OR)_2$, could not be isolated.

Addition of the tribromide (0·33 mol.) to the (+)lactate led to formation of (−)α-bromopropionate in 30% yield, apparently without any loss in rotatory power. Except that for this experiment the yield of bromide, RBr, is smaller, and there is a general loss of phosphite material probably due to hydrolysis to water soluble substances during aqueous treatment, the behaviour of ethyl (+)lactate is analogous to that of (+)β-octanol and may be explained similarly in terms of broadside and end-on collisions (Part III, *loc. cit.*).

In Tables I and II are recorded results of the addition of the phosphorus trihalide (0·33 mol.) to a mixture of ethyl (+)lactate and a tertiary base. The general effect is the rapid production, by broadside collision, of (+)*tri-α-carbethoxyethyl phosphite*, and the hydrohalide of the respective base, no halide, RX, being formed during this procedure, even when followed by heating. In this behaviour, ethyl (+)lactate resembles (+)β-octanol, ethyl (+)mandelate, and (+)phenylmethylcarbinol. Further addition of the trihalide, followed by heating (as in Darzens' procedure for thionyl chloride) gave the following results. With the trichloride, only traces of α-chloropropionate were obtained. With the tribromide, a low yield of α-bromopropionate was obtained when pyridine was the base; but high yields, accompanied by almost complete loss in rotatory power, were obtained when the base was either quinoline or dimethylaniline. In this respect, ethyl (+)lactate shows much more resemblance to ethyl (+)mandelate than to (+)β-octanol or (+)phenylmethylcarbinol. The observation also furnishes an example of a specific as well as a general behaviour of a particular tertiary base, and shows the need for caution in the employment of analogy in formulating mechanisms involving " tertiary bases."

Unlike the chlorosulphinate, RO·SO·Cl (Gerrard, *loc. cit.*; Gerrard, Kenyon, and Phillips, *loc. cit.*), the chlorophosphite, PCl_2OR, of ethyl (+)lactate did not react at ordinary temperatures with the three tertiary bases mentioned. At higher temperatures decomposition occurred; but no chloride, RCl, could be isolated. When the chlorophosphite was heated at 120—140° with the hydrochloride of the respective base, decomposition occurred and the yield of α-chloropropionate was approximately 12%. Addition of the chlorophosphite, PCl_2OR, to mixtures of ethyl lactate (2 mols.) and base (2 mols.) caused the rapid precipitation of the hydrochloride of the base, and the production of the tri-ester, $P(OR)_3$; the chlorophosphite, $PCl(OR)_2$, behaved similarly.

Addition of phosphorus oxychloride (0·33 mol.) to a mixture of (+)lactate and pyridine (1 mol.) caused a much slower precipitation of pyridine hydrochloride than did the trichloride, the other product being mainly (+)*tri-α-carbethoxyethyl phosphate*; but no α-chloropropionate was formed. In this respect, the lactate resembles β-octanol, but differs from phenylmethylcarbinol and ethyl mandelate, since with these, the chloride, RCl, was formed during the mixing (Part II, *loc. cit.*). The slower velocity of reaction may be due to the greater strength of the P—Cl links conferred upon them by the co-ordinate link $\overset{+}{P}—\overset{-}{O}$.

Further addition of the oxychloride (0·66 mol.) followed by heating up to 100°, caused the production of (—)α-chloropropionate in 36% yield without loss of rotatory power. Although Wagner-Jauregg (*loc. cit.*) showed that pyridine in addition to the oxychloride greatly increased the yield of ethyl phenylchloroacetate, he found it had no such effect in the case of ethyl lactate, a small amount only of impure α-chloropropionate being obtained. By the experiments recorded here (see also Gerrard, J., 1940, 1464; Part II, *loc. cit.*) the essential conditions for the production of the chloride, RCl, are revealed.

When two molecular proportions of pyridine were used, an increased yield of (—)α-chloropropionate was produced at 100°; but in contrast with β-octanol, a considerable loss of rotatory power occurred. As in the case of β-octanol the ether insoluble part of the reaction product appeared to be a mixture of pyridine hydrochloride and a compound, PO_2Cl,NC_5H_5, approximately in the proportion of 1 : 1 (cf. Part II).

Addition of the oxychloride (1 mol.) to mixtures of (+)lactate (1 mol.) and quinoline or dimethylaniline (1 mol.) followed by heating at 100° for 30 minutes gave, in each case, (—)α-chloropropionate in 68% yield without loss of rotatory power, and the ether insoluble products appeared to have the composition C_9H_7NHCl,PO_2Cl and $C_6H_5N(CH_3)_2HCl,PO_2Cl$ respectively.

Again, the experimental details show a marked deviation from strict analogy in the behaviour of the three bases.

EXPERIMENTAL.

Rotatory powers are recorded for $l = 1$ dm. Dry ether was used except for extraction from aqueous mixtures. The operations now reported are similar to the corresponding procedures described in Parts I, II and III. Lactic acid was resolved by morphine (Irvine, J., 1906, **89**, 935; Patterson and Forsyth, J., 1913, **103**, 2263) and esterified by the benzene–alcohol–water ternary mixture method. The ester had b. p. 58—59°/18 mm., $\alpha_D^{16°}$ +11·4°, $n_D^{16°}$ 1·4150, $d_{4°}^{20°}$ 1·0315 (Found : *M*, by hydrolysis, 118·0. Calc. : 118).

Addition of Ethyl (+)*Lactate to Phosphorus Trichloride.*—The lactate (11·8 g., 1 mol.; $\alpha_D^{16°}$ +11·4°) was added dropwise to the trichloride (27·5 g., 2 mols.) which was left at 0° and agitated by carbon dioxide. After being at 15°/15 mm. for one hour, the product was distilled. The products isolated were (+)*α-carbethoxyethoxyphosphorus dichloride*, $PCl_2O·CHMe·CO_2Et$ (15·9 g.), b. p. 88°/15 mm., $\alpha_D^{16°}$ +201·3°, $n_D^{19°}$ 1·4654, $d_{4°}^{17°}$ 1·2745, $d_{4°}^{35°}$ 1·2522 (Found : Cl, 32·6; P, 14·2. $C_5H_9O_3Cl_2P$ requires Cl, 32·4; P, 14·2%) and (+)*di-(α-carbethoxyethoxy)-phosphorus chloride*, $PCl(OR)_2$ (2·3 g.), b. p. 155—160°/15 mm., $\alpha_D^{16°}$ +160·4° (Found : Cl, 11·2. $C_{10}H_{18}O_6ClP$ requires Cl, 11·8%).

The physical constants and chlorine content of the dichloride remained unchanged after the dichloride had stood for 21 days. It could be distilled at ordinary pressure, b. p. 205°, without decomposition.

Addition of Phosphorus Trichloride to Ethyl (+)*Lactate.*—The trichloride (1·6 g., 0·33 mol.) was added dropwise to the lactate (4 g., 1 mol.) at —10° with constant shaking, and after the resulting liquid had been at room temperature for 2 hours, it was added to ice. The ethereal extract was washed with a dilute solution of sodium carbonate, dried with sodium sulphate and distilled. Ethyl (—)α-chloropropionate (1·1 g.), b. p. 53°/30 mm., $\alpha_D^{16°}$ —16·8°, $n_D^{16°}$ 1·4169, and a residue (2·0 g.), $\alpha_D^{16°}$ +79·4° (Found : P, 11·4. *Di-α-carbethoxyethyl hydrogen phosphite*, $C_{10}H_{19}O_7P$, requires P, 11·0%), were obtained.

Interaction of Phosphorus Tribromide and Ethyl (+)*Lactate.*—The product obtained by the dropwise addition of the lactate (4 g., 1 mol.) to the tribromide (18 g., 2 mols.) well shaken at —10° was allowed to stand at room temperature for

2 hours, and then added to ice. The ethereal extract after being washed with a dilute solution of sodium carbonate and dried with sodium sulphate, yielded ethyl (−)α-bromopropionate (1·6 g.), b. p. 66°/27 mm., $\alpha_D^{16^\circ}$ −42·1°, $n_D^{17^\circ}$ 1·4432 (Found : Br, 44·1. Calc. : Br, 44·2%); there was no residue. When the tribromide (1 mol.) was used the yield of bromopropionate was 2·3 g. Addition of the lactate to the tribromide (2 mol.) agitated by a stream of carbon dioxide first at −10°, then for 3 hours at 20°, followed by aqueous treatment led only to a 5% yield of the bromide, RBr, about 90% of the material being lost as water soluble substance.

Addition of the tribromide (6·0 g., 0·66 mol.) to the lactate (4 g., 1 mol.) at −10° did not cause any obvious evolution of hydrogen bromide during the mixing. After being allowed to stand at 14° for 2 hours, the mixture was added to ice. From the ethereal extract, ethyl (−)α-bromopropionate (1·9 g.), b. p. 58°/18 mm., $\alpha_D^{15^\circ}$ −44·3°, $n_D^{15^\circ}$ 1·4440 (Found : Br, 44·0. Calc. : Br, 44·2%), and a residue (0·8 g.) were obtained.

In a parallel experiment, the mixture after being allowed to warm to room temperature, was heated at 40° for 2 hours, previous to treatment with water. Ethyl (−)α-bromopropionate (1·8 g.) $\alpha_D^{15^\circ}$ −44·0°, $n_D^{8^\circ}$ 1·4481, but no undistilled residue, was obtained. It will be noticed that this more rigorous treatment did not lead to an increased yield of the bromide RBr. Almost the same yield was obtained by the use of only 0·33 mol. of tribromide.

Interaction of Phosphorus Trihalides and Ethyl (+)Lactate in the Presence of Tertiary Bases.—(a) *Using one-third mol. of phosphorus trihalide.* An ethereal solution of the trihalide (0·33 mol.) was added dropwise to an ethereal solution of ethyl (+)lactate ($\alpha_D^{16^\circ}$ +6·0°; 1 mol.) and tertiary base (1 mol.) at −10°. When the trichloride and the tribromide were used, precipitation of the hydrogen halide of the base commenced at the beginning, and was complete at the end of the operation. With the tri-iodide, no reaction appeared to take place even when the mixture was warmed; and this was attributed to the very sparing solubility of the tri-iodide in ether. The operation was, therefore, conducted in carbon disulphide and then results were obtained strictly analogous to those for the other halides except that the rate of precipitation of the hydriodide of the base was slower. After being for 2 hours at room temperature, the ethereal solution was filtered rapidly from the hydrogen halide of the base, and this salt, after being washed quickly with solvent, was placed in a vacuum desiccator for 2 hours before being weighed and analysed. The weight of the salt was almost theoretical, showing that no ethyl α-halogenopropionate could have been formed during this operation. Aqueous treatment of the ethereal solution caused serious hydrolysis which led to an undistillable mixture of phosphites. Even when aqueous treatment was not applied, distillation of the product was tedious. In the experiments in which pyridine was used, the two main products isolated were : (i) a fraction, b. p. 140—150°/2 mm., $\alpha_D^{16^\circ}$ +39·2°, $n_D^{10^\circ}$ 1·4370 (Found : P, 9·7%), most likely a mixture of di-(α-carbethoxyethyl) hydrogen phosphite (Calc. : P, 11·0%) and the tri-ester, and (ii) a fraction, b. p. 150—155°/2 mm., $\alpha_D^{16^\circ}$ +36·0°, $n_D^{10^\circ}$ 1·4382 (Found : P, 8·1. *Tri-(α-carbethoxyethyl) phosphite*, $C_{15}H_{27}O_9P$ requires P, 8·1%). When a specimen of ethyl (+)lactate ($\alpha_D^{16^\circ}$ +11·2°) was used, the tri-ester had $\alpha_D^{16^\circ}$ +79·5°. In Table I the results of the complete series of experiments are recorded. The phosphite residue was not distilled, the data refer to the liquid remaining after the ether had been evaporated and the residue kept at 30—40°/20 mm. for 2 hours (Calc. for tri-ester, $P(OR)_3$: wt. 3·18 g.).

In Table II are recorded results obtained when reagents were mixed in absence of ether, which was added after the reaction had occurred.

Table I.

Interaction of (+)Lactate ($\alpha_D^{16^\circ}$ +6·0°; 3 g., 1 mol.), Tertiary Base (1 mol.) and Phosphorus Trihalide (0·33 mol.).

Base = B.	Pyridine, 2·0 g.			Quinoline, 3·25 g.			Dimethylaniline, 3·1 g.		
Halogen = X.	PCl_3.	PBr_3.	PI_3.	PCl_3.	PBr_3.	PI_3.	PCl_3.	PBr_3.	PI_3.
Wt. PX_3	1·2	2·3	3·5	1·2	2·3	3·5	1·2	2·3	3·5
Wt. BHX	2·85	3·9	5·1	4·1	5·2	6·4	3·85	4·9	6·2
Calc.	2·90	4·0	5·2	4·14	5·25	6·4	3·94	5·05	6·25
Found : X% in BHX	30·1	49·1	59·2	20·8	38·1	47·1	20·3	39·5	49·7
Calc. : X%	30·8	50·0	61·4	21·4	38·1	49·4	22·5	39·6	51·0
Wt. of phosphite residue, g.	2·9	2·85	2·8	2·8	2·8	2·85	2·75	2·8	2·8
Found : P%	8·8	8·9	9·0	9·0	9·0	8·9	9·15	9·0	8·9
$\alpha_D^{16^\circ}$ +	42·0°	41·6°	41·8°	39·8°	39·0°	40·5°	42·0°	40·1°	36·7°

Table II.

Interaction of Phosphorus Trihalide (0·33 mol.), Ethyl Lactate (3·0 g., 1 mol.), and Tertiary Base (1 mol.) in Absence of Ether.

Tertiary base = B.	Pyridine.		Quinoline.		Dimethylaniline.	
Trihalide PX_3.	PCl_3.	PBr_3.	PCl_3.	PBr_3.	PCl_3.	PBr_3.
Wt. of base, g.	2	2	3·23	3·23	3·05	3·05
Wt. of trihalide, g.	1·6	2·6	1·6	2·6	1·6	2·6
Wt. of BHX, g.	2·85	4·0	4·1	5·1	3·85	4·8
Calc. : Wt. BHX, g.	2·9	4·0	4·14	5·25	3·95	5·05
Found : X%	28·8	47·4	20·6	37·0	21·4	39·1
Calc. : X%	30·8	50·0	21·4	38·1	22·5	39·6
Wt. of residue from evaporation of ethereal extract, g.	3·1	2·8	2·8	2·8	3·1	3·5
Found : P%	—	7·6	—	—	—	—

(b) *Using one mol. of phosphorus trihalde.* To a solution of ethyl (+)lactate ($\alpha_D^{16^\circ}$ +3·4°; 4 g., 1 mol.) and pyridine (2·7 g., 1 mol.) in ether (10 c.c.), phosphorus trichloride (4·6 g., 1 mol.) in ether (5 c.c.) was added dropwise at −10°. During the addition of the first one-third of the trichloride, the behaviour of the system was precisely as described in (*a*); but there was no apparent effect during the addition of the remainder of the reagent. The product was heated on a steam-bath for 1 hour, the ether being allowed to evaporate through a tube so that the temperature of the mixture could be raised to 90—95°. After the semi-solid mass which remained on cooling had been stirred with ether, the mixture was filtered rapidly, the residue being washed with ether, and placed in a vacuum desiccator for 1 hour. It then weighed 4·05 g. (Calc. for C_5H_5N,HCl : 3·85 g.) (Found : Cl, 28·2; C_5H_5N, 62·4%). Evaporation of the ethereal solution, which was washed with a dilute solution of sodium carbonate and dried with sodium sulphate, gave a residue (0·3 g.), there being no more than a drop of distillate, with oil bath temperature up to 110°/23 mm. The aqueous washing of the ethereal solution contained 1·60 g. of chloride ion. In a parallel experiment, the same quantities of reagents were mixed as described, except that ether was omitted. A precipitate formed as described for the previous experiment. The mixture was heated under reflux for 3 hours at 100°, the precipitate, which was molten at the higher temperature, crystallised again on being cooled. Ether was added, and the crystalline mass was separated, washed with ether and kept in a vacuum desiccator for 2 hours. It then weighed 3·94 g. (Calc. for C_5H_5N,HCl : 3·85 g.) (Found : Cl, 29·2. Calc. : Cl, 30·8%). The ethereal solution was poured on ice, washed with a minimum amount of solution of sodium carbonate, dried (sodium sulphate) and evaporated. Only a trace of residue was obtained, and only part of this was volatile.

It appears from these results that the phosphite formed during the addition of the first third of the trichloride is converted into a mixture of the dichlorophosphite and monochlorophosphite at the elevated temperature, and these do not yield chloride, RCl, in the presence of the hydrochloride of the base; but are hydrolysed to soluble products during the treatment with water. It therefore appears that there is no analogy with the mechanism of Darzens' procedure.

By following the same procedure with phosphorus tribromide (9·0 g., 1 mol.), ethyl lactate (4 g., 1 mol.) and pyridine (2·7 g., 1 mol.) no more than 0·4 g. of ethyl α-bromopropionate, b. p. 59—60°/20 mm., $n_D^{14°}$ 1·4420, and 0·3 g. of residue were obtained. The solid weighed 5·53 g. (Calc. for pyridine hydrobromide based on first phase of the reaction : 5·30 g.) (Found : Br, 50·2; C_5H_5N, 49·0. Calc. for C_5H_5N,HBr : Br, 50·0; C_5H_5N, 49·4%). The aqueous washing of the ethereal solution contained 4·53 g. of bromide ion.

With quinoline (4·3 g., 1 mol.) as base, and phosphorus trichloride (4·6 g., 1 mol.), 0·35 g. of α-chloropropionate, and a residue (0·3 g.) were obtained; and similar results were obtained with the trichloride when the base was dimethylaniline (4·03 g., 1 mol.).

The tribromide (9·0 g., 1 mol.) was added to a mixture of quinoline (4·3 g., 1 mol.) and lactate (4·0 g., 1 mol.) in the absence of ether at 0°. After the mixture had been heated for 1 hour at 100°, ether was added, and the insoluble part separated by filtration. The solid was kept under reduced pressure for 2 hours, and it then weighed 7·36 g. (Calc. for quinoline hydrobromide : 7·0 g.) (Found : Br, 37·0. Calc. : Br, 38·1%). From the washed and dried ethereal solution, ethyl (—)α-bromopropionate (3·4 g.), b. p. 46°/9 mm., $n_D^{9°}$ 1·4471, $\alpha_D^{16°}$ $-2·0°$ (Found : Br, 44·2. Calc. : Br, 44·2%) was obtained.

With dimethylaniline as base (4·0 g., 1 mol.), the results were : solid (6·6 g.) (Found : Br, 38·0. Calc. for $PhNMe_2,HBr$: Br, 39·6%), and (—)α-bromopropionate (4·0 g.), b. p. 46°/9 mm., $n_D^{9°}$ 1·4472, $\alpha_D^{16°}$ $-1·1°$ (Found : Br, 44·1%).

Interaction of α-Carbethoxyethoxyphosphorus Dichloride and Tertiary Bases.—Only very slight warming occurred when the dichloride was mixed with the tertiary base at ordinary temperature, and a slight precipitate was formed. In this series of experiments, the tertiary base (2 mol.; pyridine 1·6 g., quinoline 2·6 g., dimethylaniline, 2·45 g.) was added to the dichloride (2·2 g., 1 mol.) in a test-tube at 0°. Nine mixtures were so produced, three for each base. After these had been allowed to stand at the specified temperature, they were each poured into separate volumes of ether each containing 1·0 g. (2 mol.) of ethyl alcohol in order to extract as hydrochloride of the base any chloride ion, or any unreacted dichloride in the system, $PCl_2(OR) + 2\ Base + 2\ EtOH = P(OEt)_2OR + 2\ Base,HCl$.

Three of the primary mixtures (one for each base) were kept at 15° for 5 hours; but there was no sign of any reaction. They each produced a white precipitate when poured into ether containing 1·0 g. of ethyl alcohol. The solid was separated, place under reduced pressure for 2 hours, and analysed :

Base = B.	Wt. of B,HCl.		% Cl in B,HCl.	
	Found.	Calc	Found.	Calc.
Pyridine	2·3	2·31	29·6	30·8
Quinoline	3·3	3·31	19·9	21·4
Dimethylaniline	3·0	3·17	21·5	22·5

The ethereal solution was washed once with a small volume of water, and it was found that this aqueous extract did not contain any chloride ion. The residue (1·1 g.) from the dried ethereal solution was partly volatile with indications of slow decomposition (b. p. 55—70°/10 mm.); but no α-chloropropionate could be isolated, a result in accordance with the determined amount of chlorine in the hydrochloride of the base.

Three more of the mixtures (again one for each base) were kept at 60° for 3 hours. With quinoline and dimethylaniline respectively, there was no sign of reaction. On being poured into ether containing 1·0 g. (2 mols.) of ethyl alcohol, both mixtures gave white precipitates which were separated as previously described :

Base = B.	Wt. of B,HCl.		% Cl in B,HCl.	
	Found.	Calc.	Found.	Calc.
Quinoline	3·3	3·31	20·0	21·4
Dimethylaniline	2·9	3·17	21·2	22·5

Each ethereal solution was washed with a little water (the aqueous extract was free from chloride ion), dried and evaporated. Each residue behaved as already described.

In the case of pyridine, at 60°, signs of decomposition appeared, and an orange curdy solid separated. The mixture was added to ethyl alcohol (1·0 g.) in ether. A copious precipitate was produced and some gummy material was left. The white precipitate weighed 1·60 g. (Found : Cl, 28·6%), and the ethereal solution, which was free from chloride ion, yielded 1·0 g. of residue partly volatile, b. p. 55—65°/10 mm., and therefore did not contain any α-chloropropionate.

When the remaining three mixtures were heated at 110° for 2 hours deep seated decomposition occurred, and a thick sticky mass (orange-coloured) was formed. The gummy mass gave off heavy white fumes in moist air. It was transferred to ether containing 1·0 g. ethyl alcohol and then treated with water at once, separation by filtration being impossible. An orange finely divided solid separated; it was insoluble in ether and in water and interfered considerably with the separation of these two liquids. Each ethereal solution yielded approximately 0·9 g. of residue, half of which was volatile, b. p. 60—65°/10 mm., there being no indication of α-chloropropionate.

When the dichloride was heated for 2 hours at 120—140° with the hydrochloride of the base, instead of the base itself, much smaller amounts of the orange solid formed. The product was added to ice, and extracted with ether. The residue, left on evaporation of the ether, was mostly volatile, b. p. under 42°/10 mm., and represented 12—15% of the chloride RCl.

Interaction of α-Carbethoxyethyloxyphosphorus Dichloride and Ethyl Lactate in the Presence of Tertiary Bases.—The dichloride, PCl_2OR (2·2 g., 1 mol.), in ethereal solution was added to an ethereal solution of ethyl lactate (2·36 g., 2 mols.)

and tertiary base (2 mols.) at 0°. The hydrochloride of the base was precipitated at once and there appeared to be no essential differences in behaviour of the three bases used. The solid was separated, the ethereal solution evaporated without previous treatment with water and the clear colourless residue was heated up to 110°/15 mm.; there was a trace of distillate at 50°/15 mm., and the final residue was weighed and examined. From the appropriate results which are recorded below, the residues appear to be specimens of the tri-ester, $P(OR)_3$.

Base = B.	Pyridine, 1·6 g.	Quinoline, 2·6 g.	Dimethylaniline, 2·45 g.
Wt. B,HCl, Found	2·2 g.	3·3 g.	3·1 g.
Calc.	2·3 g.	3·31 g.	3·2 g.
Wt. of residue	3·15 g.	3·10 g.	3·3 g.
$n_D^{20°}$	1·4352	1·4400	1·4420
Found : P %	8·8	8·6	8·7

Interaction of Ethyl (+)*Lactate and Phosphorus Oxychloride in the Presence of Tertiary Bases.*—(a) *Using one-third mol. of oxychloride and one mol. of base.* The oxychloride (2·6 g., 0·33 mol.) was added dropwise to an ethereal solution (20 c.c.) of ethyl (+)lactate, $\alpha_D^{16°}$ +11·2° (5·9 g., 1 mol.), and pyridine (4 g., 1 mol.) at −10°. A white solid was precipitated from the beginning of the operation; and, after 2 days the mixture was filtered. The solid was washed with ether and, after it had been under reduced pressure for 2 hours, it weighed 5·6 g. (Calc. for C_5H_5N,HCl: 5·8 g.) (Found: Cl, 29·4; C_5H_5N, 69·0. Calc.: Cl, 30·8; C_6H_5N, 68·4%). Without previous aqueous treatment, the ethereal solution was evaporated, and after the liquid residue had been kept at 40°/20 mm. for 2 hours, it weighed 6·22 g. (Calc. for the phosphate $OP(OR)_3$: 6·63 g.) and had $\alpha_D^{16°}$ +55·6°, $d_{4°}^{20°}$ 1·200, $n_D^{18°}$ 1·4350 (Found: P, 7·9. *Tri-α-carbethoxyethyl phosphate*, $C_{15}H_{27}O_{10}P$, requires P, 7·8%). This substance could not be distilled.

With quinoline (4·3 g., 1 mol.) and lactate (4·0 g., 1 mol.) a white precipitate was formed much more slowly than with pyridine. This white solid weighed 5·45 g. (Calc. for quinoline hydrochloride: 5·51 g.) (Found: Cl, 20·4. Calc.: Cl, 21·4%); and the residue from the evaporation of the ethereal solution weighed 3·1 g. (after being at 120°/14 mm. for 30 minutes) and was thick and cloudy.

With dimethylaniline (4·0 g., 1 mol.) and lactate (4·0 g., 1 mol.) a distinctly different type of behaviour was encountered. No solid separated during the mixing; but, when the liquid was allowed to stand at room temperature, a liquid gradually separated and did not solidify during two days. The ethereal solution was decanted, and after the liquid residue had been washed with ether and then left under reduced pressure for 2 hours, it weighed 6·56 g. (Found: Cl, 15·5%). This liquid, which weighed more than the sum of the weight of base and oxychloride, contained nearly all the chlorine in the system and could not have been merely dimethylaniline hydrochloride. From the ethereal solution a distillate (1·9 g.), b. p. 56—60°, and a residue (0·9 g.) were obtained. This peculiar behaviour is being examined further.

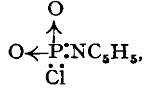
(b) *Using one mol. of oxychloride and one mol. of base.* The oxychloride (8·1 g., 1 mol.), added dropwise to a mixture of ethyl (+)lactate (4·0 g., 1 mol.) and pyridine (2·7 g., 1 mol.) at 0° (in absence of ether), caused the slow precipitation of pyridine hydrochloride. After being heated on a steam-bath for 45 minutes, during which procedure the reaction mixture existed as two liquid layers, the mixture was cooled and the lower layer solidified to white crystalline mass. Ether was added, and the solution was rapidly separated from the crystalline mass which was washed with ether and, after being under reduced pressure for 2 hours, it weighed 6·54 g. (Found: Cl, 29·9; P, 14·0; C_5H_5N, 41·2%). This corresponds approximately with C_5H_5N,HCl,PO_2Cl, and it contains 90% of the phosphorus in the system. The filtered ethereal solution was added to ice and, after being washed and dried, it yielded ethyl (−)α-chloropropionate (1·65 g., 36%), b. p. 46°/18 mm., $\alpha_D^{16°}$ −21·8°, and a residue (1·0 g.).

Formation of chloride, RCl, did not occur during the addition of the oxychloride or on subsequent standing at room-temperature. In a parallel experiment, ether was added after the mixing, and the ethereal solution was separated from the pyridine hydrochloride (4·01 g. Found: Cl, 30·6%), and poured onto ice. The residue from the washed and dried ethereal solution gave no distillate, oil bath at 130°/10 mm. The first stage is evidently the formation of the phosphate by the oxychloride (0·33 mol.) and the second stage is the interaction of the oxychloride (0·66 mol.) and the phosphate (0·33 mol.), the chloride, RCl, being produced during the subsequent heating at 100°.

With quinoline (4·3 g., 1 mol.) as the base, there was a slow precipitation of solid at 0°. On the steam-bath (30 minutes) a colourless homogeneous liquid was produced; but the addition of ether then caused the separation of a viscous liquid which, after being separated from the ethereal solution by decantation and then kept under reduced pressure for 2 hours, weighed 8·8 g.; it dissolved in water (Found: Cl, 24·5; P, 11·6%, *i.e.*, all the phosphorus in the system). From the ethereal solution, after this had been washed and dried, ethyl (−)α-chloropropionate (3·1 g.), b. p. 45°/19 mm., $\alpha_D^{16°}$ −21·6°, $n_D^{16°}$ 1·4169, was obtained. The weight and analysis of the ether insoluble part corresponds fairly closely to C_9H_7N,HCl,PO_2Cl (Calc.: Cl, 26·9; P, 11·7%).

With dimethylaniline (4·0 g., 1 mol.) as base, no precipitate was obtained. Addition of ether, after the liquid had been on the steam-bath for 30 minutes, caused the separation of an oil, which, after separation by decantation and being kept under reduced pressure for 2 hours, weighed 8·2 g. and dissolved completely in water (Found: Cl, 22·8; P, 11·8%, *i.e.*, nearly all the phosphorus in the system). From the washed and dried ethereal solution, ethyl (−)α-chloropropionate (3·1 g.), b. p. 45°/19 mm., $\alpha_D^{16°}$ −21·6, $n_D^{17°}$ 1·4168, was obtained. Here again the weight and analysis of the ether insoluble part correspond approximately to $C_6H_5N(CH_3)_2,HCl,PO_2Cl$.

(c) *Using oxychloride* (1 *mol.*) *and base* (2 *mols.*). To a mixture of ethyl (+)lactate (5·3 g., 1 mol.) and pyridine (7·1 g., 2 mols.) at −10°, the oxychloride (6·9 g., 1 mol.) was added dropwise, and the resulting mixture was then heated at 90—95° for 1 hour. The pasty mass remaining when the mixture was cooled was extracted with ether, and the portion insoluble in ether, after being under reduced pressure for 2 hours, weighed 13·35 g. (Found: Cl, 22·8; P, 9·6; C_5H_5N, 49·0%). Ethyl (−)α-chloropropionate (3·8 g.), b. p. 56—57°/31 mm., 143—144°/755 mm., $\alpha_D^{16°}$ −4·8°, $d_{4°}^{19°}$ 1·0760, $n_D^{18°}$ 1·4155, was obtained from the washed and dried ethereal solution.

The pasty mass was probably a mixture of pyridine hydrochloride (A), formed during the addition of the first 0·33 mol. of oxychloride, and a compound (B) of the type  $O \leftarrow \overset{\overset{O}{\uparrow}}{\underset{\ddot{Cl}}{P}}\colon NC_5H_5$, formed during the subsequent heat-treatment, approximately in molecular proportion (Calc.: Cl, 24·2; P, 10·6; C_5H_5N, 53·9%).

The authors thank the Chemical Society for a grant from the Research Fund, and Dr. R. W. West, for helpful discussions.

THE NORTHERN POLYTECHNIC, HOLLOWAY ROAD, N.7.

[*Received, August* 14*th*, 1945.]