[Contribution from the Chemical Laboratory of Iowa State College]

ORGANOLEAD SALTS

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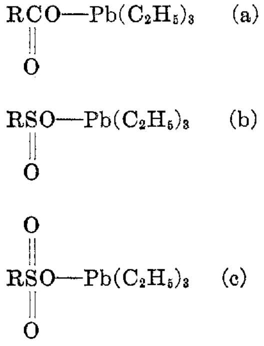
The sternutatory and irritating properties of some triethyllead salts have already been noted in the literature (1–3). Similar properties have recently been reported for tri-*n*-propyl- and tri-*n*-butyl-lead salts, the former being described as the most potent of the homologous trialkyllead compounds examined to date (4–6). It was of interest to us to prepare various mono-triethyllead (I) and poly-triethyllead salts (II) in order to determine the effect of the molecular structure of the anion on the sternutatory properties of the salt. The choice of the triethyllead radical as the cation was determined primarily by the easy availability of the tetraethyllead from which the cation may be derived by various means. Incidental to these studies, a number of diethyllead salts (III) were also prepared, but none of these exhibited sternutatory activity. In all, forty-four new compounds were prepared, derived from substituted acetic acids, unsaturated aliphatic acids, arylcarboxylic acids, heterocyclic acids, alkyl and aryl sulfonic and sulfinic acids, polybasic acids, a sulfonamide, and a miscellany of other acids. The attempted preparations of ten other organolead compounds are described briefly.

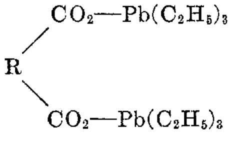


$R\underset{\underset{\displaystyle O}{\|}}{C}O{-}Pb(C_2H_5)_3$ (a)

$R\underset{\underset{\displaystyle O}{\|}}{S}O{-}Pb(C_2H_5)_3$ (b)

$R\overset{\overset{\displaystyle O}{\|}}{\underset{\underset{\displaystyle O}{\|}}{S}}O{-}Pb(C_2H_5)_3$ (c)

I



II

$(R{-}CO_2)_2Pb(C_2H_5)_2$

III

Although the quantitative evaluation of the relative efficacies was not undertaken in these laboratories, it may be safely stated that the triethyllead cation will, as a rule, endow the resulting molecule with sternutatory activity and that the intensity of this action will be modified by the radical employed as the anion. Of the various triethyllead salts prepared, only those (IV and V) derivable from thiocyanic and selenocyanic acids, showed no activity. Likewise, diethyllead selenite (VI), prepared primarily for toxicity studies, was devoid of sternutatory

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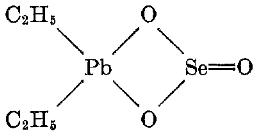
activity. Compound V (m.p. 33–34°), prepared in 88–93% yield by a double decomposition reaction (Table IV) between triethyllead acetate and potassium selenocyanate, is distinguished by the interesting sequence of carbon to metal to metalloid to carbon linkages. Our compound compares favorably with that (m.p. 29.5–30.5°) prepared by Heap and Saunders (5) from the reaction between triethyllead chloride and potassium selenocyanate. The latter procedure gave a 62% yield of product.

$(C_2H_5)_3PbSCN$

IV

$(C_2H_5)_3PbSeCN$

V



VI

The thiocyanate (IV), melting at 26.5–27°, was obtained in 90–93% yield, also from the organolead acetate, whereas the British workers obtained the same compound (m.p. 35°) in 60% yield from the triethyllead chloride.

Three general methods (A, B, and C) were used for the preparation of the salts (1, 2). In method A, tetraethyllead is cleaved by the acid to give, in some cases, the triethyllead salt; in others, the diethyllead salt. An examination of our results and existing data reveals the absence of any relationship between acid strength

$$(C_2H_5)_4Pb + RCOOH \rightarrow RCOOPb(C_2H_5)_3 + C_2H_6 \uparrow \qquad (A)$$

and/or

$$(C_2H_5)_4Pb + 2RCOOH \rightarrow (RCOO)_2Pb(C_2H_5)_2 + 2C_2H_6 \uparrow \qquad (A)$$

$$(C_2H_5)_3Pb\text{—}O\text{—}COCH_3 + RCOONa \rightarrow RCO_2Pb(C_2H_5)_3 + CH_3CO_2Na \qquad (B)$$

$$(C_2H_5)_3PbOH + RCOOH \rightarrow RCO_2Pb(C_2H_5)_3 + H_2O \qquad (C)$$

and the extent of alkyl-lead cleavage (see discussion). For example, with *m*-bromobenzoic acid and tetraethyllead, both types of salts are produced. Certainly, the solvent employed is a determining factor in the extent of alkyl-lead cleavage. Thus, the treatment of tetraethyllead with *m*-nitrobenzoic acid in ethanolic solution yields triethyllead *m*-nitrobenzoate. This compound may be obtained with or without the use of silica gel as catalyst, and a large excess (100%) of the acid does not produce a second alkyl-lead cleavage. Furthermore, triethyllead *m*-nitrobenzoate may be boiled in ethanol without subsequent transformation. If, on the other hand, triethyllead *m*-nitrobenzoate is boiled with benzene in the process of recrystallization, further reaction (possibly disproportionation) sets in and the salt isolated is diethyllead di-*m*-nitrobenzoate. Also, when *m*-nitrobenzoic acid is reacted with tetraethyllead in benzene as solvent, a vigorous reaction occurs and the volume of ethane evolved shows that two ethyl groups have been cleaved. A nearly quantitative yield of diethyllead di-*m*-nitrobenzoate is obtained.

Method B is useful with acids difficultly soluble in organic solvents. An aqueous solution of the alkali salt of the acid is treated with an aqueous solution of triethyllead acetate; the newly formed organolead compound precipitates almost instantaneously, while the sodium acetate remains in solution. There is no superior alternative to method B when the parent acid can best be handled as the sodium or potassium salt. Thus, this procedure proved very useful in the syntheses of the triethyllead thiocyanate and selenocyanate salts. This method is also practicable for the preparation of organolead sulfinates and sulfonates, since the parent acids are generally available only as the alkali salts.

Method C, which is a neutralization reaction between an acid and a relatively strong base, was the one most commonly used in this investigation. The method, however, suffers certain side reactions. Oftentimes, when equimolar proportions of the organolead base and the acid were reacted to form the triethyllead salt, a diethyllead compound was obtained instead. This phenomenon occurred with nicotinic, N-*n*-butylanthranilic, *p*-toluic, *p*-chlorobenzoic, and *m*-nitrobenzoic acids. The formation of such compounds may be described as taking place through the following sequence of reactions:

$$(C_2H_5)_3PbOH + RCOOH \rightarrow (C_2H_5)_3Pb\text{—}O\text{—}COR + H_2O$$
$$(C_2H_5)_3Pb\text{—}O\text{—}COR + RCOOH \rightarrow (C_2H_5)_2Pb\text{—}(O\text{—}COR)_2 + C_2H_6 \uparrow$$

The elimination of water probably occurs first but the secondary reaction may possibly be avoided by working at moderate temperatures. As with method A, the solvent employed in the reaction or in the recrystallization is sometimes a factor in determining the formation of the triethyl- or the diethyl-lead salt. For example, in ethanol, the reaction between equimolar quantities of *p*-chlorobenzoic acid and triethyllead hydroxide yields the triethyllead salt and in ethanol-dioxane, the diethyllead di-*p*-chlorobenzoate.

A second limitation of method C lies in the ability of the organolead base to remove the acetyl group from an acetoxy compound. Acetylsalicylic acid yields triethyllead salicylate instead of the expected triethyllead acetylsalicylate.

EXPERIMENTAL

All melting points are uncorrected.

All lead determinations were made by the method of Gilman and Robinson (7).

Triethyllead salts from triethyllead hydroxide. Method C. (a) Table I comprises a list of triethyllead salts prepared from the organolead base (1) and various acids under the following conditions. An ethanolic solution of the base was added to an equivalent amount of the acid also dissolved in 95% ethanol. The base was added in slight excess until the solution reacted faintly alkaline to litmus. After standing for ½ hour, the solution was poured upon crushed ice and the crude salt was removed by filtration. The product was redissolved in ethanol, filtered, and the filtrate diluted with water to incipient crystallization. The product was filtered off, washed with water, and dried *in vacuo* over concentrated sulfuric acid.

The preparation of triethyllead *p*-nitrobenzoate illustrates the procedure. Five g. (0.016 mole) of triethyllead hydroxide, dissolved in 25 cc. of ethanol, was poured into a solution of 2.68 g. (0.016 mole) of *p*-nitrobenzoic acid in 20 cc. of ethanol. The solution was allowed to stand for 15–30 minutes and then poured into ice-water. The solid was recrystallized from alcoholic solution by dilution with water. The fine, white needles melted at 167–168.5° with decomposition.

(b) Table II comprises a second group of triethyllead compounds, also prepared by method C, but characterized by variations in processing and recrystallization. An alcoholic solution of the acid was added to a clear alcoholic solution of the base, present in very slight excess. If the acid was difficultly soluble in ethanol, it was brought into solution by the addition of a few ccs. of dioxane before treatment with the base. The concentrations of the reactants approximated those used in the preparation of triethyllead *p*-nitrobenzoate. The reaction solution was diluted with water until crystallization set in, cooled in the refrigerator, and filtered. A second crop of crystals of equal or slightly lesser purity was usually obtained by dilution of the filtrate, followed by cooling. Sometimes, as with the diphenylacetate and the lepidine-2-carboxylate, precipitation of the salt occurred without aqueous dilution. The yields given in Table II represent the total yield of pure product, obtained after recrystallization, generally from Skelly Solve B-benzene mixture, or less often, from ethanol and water.

Other variations of method C are described under the individual compounds not listed in either Table I or II.

Triethyllead phenylacetate. A solution of 1.31 g. (0.01 mole) of phenylacetic acid in 25 cc. of ethanol was added to 3.0 g. (0.01 mole) of triethyllead hydroxide in 10 cc. of ethanol. The solution was evaporated *in vacuo* over sulfuric acid until crystallization set in. The crystals were filtered off, washed with Skelly Solve A, and dried over sulfuric acid. The compound, melting at 96–97°, was very soluble in alcohol and benzene; less soluble in ligroin and ethyl ether. The yield was 0.8 g. (19%).

TABLE I

TRIETHYLLEAD SALTS PREPARED BY METHOD C. (Group a)

TRIETHYLLEAD SALT	YIELD, %	M.P., °C.	Pb ANALYSIS	
			Calc'd, %	Found, %
α-Chlorocrotonate	75	153–155	50.09	50.17
Cinnamate	87	122–123, dec.	47.05	46.97
Furylacrylate[a]	50	132–133, dec.	48.05	48.09
β-Benzoylacrylate	79	139–141, dec.	44.15	44.26
Furoate[b]	55	156–157, dec.	51.14	51.25
o-Bromobenzoate	30	134–135	41.93	42.03
p-Bromobenzoate	45	127–128	41.93	41.93
p-Chlorobenzoate[c]	80	123–124	46.06	46.26
p-Iodobenzoate	28	129.5–130.5	38.29	38.22
p-Anisate	57	97–98	46.54	46.35
o-Nitrobenzoate[d]	36	142–143, dec.	45.02	44.81
p-Nitrobenzoate[e]	63	167–168.5, dec.	45.02	45.09
p-Aminobenzenesulfonamide[f]	62	173–174	44.54	44.63

[a] The product obtained by method A is reported to melt at 119–121° (2) and was probably impure, as indicated by the low lead content of 47.63%. [b] The furoate derivative has also been prepared by the tetraethyllead method (2). [c] The preparation of the diethyllead di-*p*-chlorobenzoate from triethyllead hydroxide and *p*-chlorobenzoic acid under other conditions is described elsewhere in this paper. [d] The reaction solution required an *in vacuo* concentration over sulfuric acid prior to processing. [e] The triethyllead *p*-nitrobenzoate was also prepared in 25% yield by method A; m.p. 168–169°. [f] The same compound (m.p. 171°), referred to as *N-(triethylplumbi)sulfanilamide*, was prepared independently and in almost identical manner by Saunders (6).

Anal. Calc'd for $C_{14}H_{22}O_2Pb$: Pb, 48.25. Found: Pb, 48.29.

A m.p. of 101–106° has been reported (2) for this compound prepared by method A.

Triethyllead triphenylacetate. An alcoholic solution of the organolead base was mixed with an equivalent of triphenylacetic acid in dioxane and after several minutes, the whole solution was poured into water to give a quantitative yield of the crude salt. The product was dissolved in an alcohol-dioxane solution and the latter diluted with a few drops of water to the point of crystallization. The fine, white crystals obtained after thorough cooling melted at 134–136° with decomposition.

Anal. Calc'd for $C_{26}H_{30}O_2Pb$: Pb, 35.65. Found: Pb, 35.80.

Triethyllead N-methylanthranilate. A solution of 1.5 g. (0.01 mole) of N-methylanthranilic acid in 15 cc. of water and 20 cc. of ethanol was added to an equivalent of triethyllead hydroxide in 15 cc. of ethanol. After evaporation of the solution to dryness over sulfuric acid, the brown crystalline residue was triturated with absolute ethanol and filtered. The filtrate was evaporated to dryness and the residue recrystallized twice from benzene diluted with Skelly Solve A. The compound, melting at 132.7° with decomposition, was obtained in a yield of 0.5 g. (11.4%).

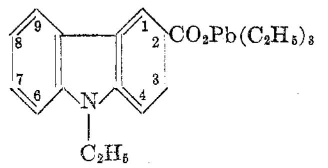
Anal. Calc'd for $C_{14}H_{23}NO_2Pb$: Pb, 46.60. Found: Pb, 46.79.

Triethyllead D-*camphor-10-sulfonate.* (a) An ethanolic solution of equimolecular quantities of D-camphor-10-sulfonic acid and triethyllead hydroxide was concentrated by distillation under reduced pressure until crystallization occurred. After two recrystallizations from a benzene-Skelly Solve B mixture, the salt melted at 172° with decomposition. The yield was 39.8%.

TABLE II

TRIETHYLLEAD SALTS PREPARED BY METHOD C. (Group b)

TRIETHYLLEAD SALT	YIELD, %	M.P., °C.	Pb ANALYSIS	
			Calc'd, %	Found, %
m-Bromobenzoate	62.5	113–114	41.94	40.99 41.01
o-Iodobenzoate	50.4	138.5–139	38.29	38.30
m-Iodobenzoate	53.3	135–136	38.29	38.20
N-Phenylanthranilate	81.6	124.5–125	40.92	40.63
Phenylpropiolate	90.0	149–150, dec.	47.19	46.80
9-Fluorenecarboxylate	23.7	Darkens at 195–196, and decomposes at 208.	41.18	41.06
N-Ethylcarbazole-2-carboxylate[a]	76.0	195, dec.	38.92	38.43
Lepidine-2-carboxylate	86.0	Melts at 153–155, and resolidifies at higher temperature to a dark body, which decomposes at 197–199.	43.19	42.73
β-2-Naphthoylpropionate	78.8	134.5	39.76	39.36
Diphenylacetate	84.0	164–165	41.0	40.76

[a]


Anal. Calc'd for $C_{16}H_{30}O_4PbS$: Pb, 39.44. Found: Pb, 39.68.

(b) Method A constitutes an excellent preparation for this compound. A suspension of a few finely powdered granules of silica gel in a solution of 40 g. (0.172 mole) of D-camphor-10-sulfonic acid, 54.8 g. (0.169 mole) of tetraethyllead (hood!) and 120 cc. of absolute ethanol was heated on a water-bath for several hours until the evolution of ethane practically ceased. The catalyst was removed and the solvent was distilled under reduced pressure. The white, crystalline residue (m.p. 166–169° with decomposition) weighed 89 g. (96.4%). Recrystallized from benzene and Skelly Solve B, the compound melted at 172°. The yield of pure product was 79 g. (86.3%).

A mixture m.p. with the salt prepared from triethyllead hydroxide showed no depression.

Anal. Calc'd for $C_{16}H_{30}O_4PbS$: Pb, 39.44. Found: Pb, 39.07.

Triethyllead salicylate from salicylic acid. A solution of 2.22 g. (0.016 mole) of salicylic acid in 20 cc. of ethanol was treated with 5 g. (0.016 mole) of triethyllead hydroxide. The solution was poured upon ice and the crude product recrystallized from alcohol-water. The salt, obtained in a yield of 3.6 g. (52%), melted at 74.5–75.5°.

Anal. Calc'd for $C_{13}H_{20}O_3Pb$: Pb, 48.05. Found: Pb, 48.09.

The preparation of this compound by method A (2) appears to have yielded a slightly impure product, as indicated by the wide m.p. range (83–91°) and the relatively low lead analyses (47.51, 47.47%). The possible contaminants may be the diethyllead disalicylate or the diethyllead diphenoxide, the latter obtained from the action of the tetraethyllead on the phenolic hydrogen. The preparation of diethyllead *bis*-*p*-nitrophenoxide from tetraethyllead and *p*-nitrophenol has been described (4).

Triethyllead salicylate from acetylsalicylic acid. To 5 g. (0.016 mole) of triethyllead hydroxide in 20 cc. of ethanol was added 2.88 g. (0.016 mole) of acetylsalicylic acid in 20 cc. of the same solvent. The solution was poured upon crushed ice, and the solid which came down was recrystallized from ethanol and a little water. The yield of compound, melting at 75–76°, was 1.8 g. (26%).

Anal. Calc'd for triethyllead acetylsalicylate, $C_{15}H_{22}O_4Pb$: Pb, 45.32. Found: Pb, 48.03.
Calc'd for triethyllead salicylate, $C_{13}H_{20}O_3Pb$: Pb, 48.05. Found: Pb, 48.03.

The identity as triethyllead salicylate was confirmed by a mixture m.p. with an authentic specimen prepared from triethyllead hydroxide and salicylic acid.

Triethyllead m-nitrobenzoate and diethyllead di-m-nitrobenzoate. To 5 g. (0.016 mole) of triethyllead hydroxide in 10 cc. of ethyl ether and 10 cc. of ethanol was added 2.68 g. (0.016 mole) of *m*-nitrobenzoic acid in 20 cc. of ethanol. The solution was evaporated *in vacuo* almost to dryness. After filtration, the residue was crystallized from hot benzene and ligroin to yield 0.8 g. (8.3%) of a crystalline material, melting with decomposition at 179–180°. The filtrate, on standing, deposited a second crop of crystals in a yield of 2.2 g. (29.7%). These melted at 172–173° with decomposition. A mixture m.p. of both crops was depressed to 150–156°.

The higher-melting fraction, soluble in ethanol and less soluble in benzene, is the diethyllead di-*m*-nitrobenzoate.

Anal. Calc'd for $C_{18}H_{18}N_2O_8Pb$: Pb, 34.70. Found: Pb, 35.20.

The lower-melting fraction, soluble in ethanol or chloroform and decomposed by boiling benzene, is the triethyllead *m*-nitrobenzoate.

Anal. Calc'd for $C_{13}H_{19}NO_4Pb$: Pb, 45.02. Found: Pb, 44.81.

Effect of solvent on the course of organolead salt formation. (a) Two equivalents (8.55 g.) of *m*-nitrobenzoic acid, dissolved in 50 cc. of ethanol and refluxed with one equivalent of tetraethyllead on a water-bath for 6 hours, liberated only one equivalent of ethane (97% yield). The evolution of gas was slow and continuous. Addition of silica gel did not increase the extent of carbon-lead cleavage. From the reaction solution, there was obtained 3 g. (26%) of triethyllead *m*-nitrobenzoate, melting at 172–173° with decomposition.

Anal. Calc'd for $C_{13}H_{19}NO_4Pb$: Pb, 45.02. Found: Pb, 45.15.

(b) Replacement of the ethanol by benzene as solvent produced a vigorous evolution of gas from the tetraethyllead/*m*-nitrobenzoic acid mixture. The reaction ceased within 2 hours and the ethane liberated (89% yield) indicated the cleavage of two ethyl groups from the tetraethyllead. The crude diethyllead di-*m*-dinitrobenzoate was filtered and recrystallized from boiling ethanol to yield 9.4 g. (62%) of yellow needles, melting at 179–180° with decomposition.

Anal. Calc'd for $C_{18}H_{18}N_2O_8Pb$: Pb, 34.70. Found: Pb, 34.61.

That the double cleavage of tetraethyllead is a step-wise procedure is suggested by the following observations. The *m*-nitrobenzoic acid is difficultly soluble in the quantity of hot benzene used. As the reaction proceeds, the acid gradually dissolves until complete solution is effected. The amount of triethyllead salt which would form as the intermediate is very easily soluble in the quantity of benzene used. Toward the end of the reaction, another solid, yellow in color, is deposited. This solid, the diethyllead salt, is very difficultly soluble in hot benzene.

(c) A preparation of triethyllead *m*-nitrobenzoate was made from 10 g. (0.06 mole) of *m*-nitrobenzoic acid and 9.3 g. (0.03 mole) of triethyllead hydroxide in 50 cc. of ethanol. The heating of this solution on the water-bath for one hour produced no evolution of gas. However, the addition of 25 cc. of benzene and further heating effected a vigorous evolution of ethane and the deposition of 11.7 g. (77% yield) of the yellow diethyllead salt. After crystallization from boiling ethanol, the product melted with decomposition at 179–180.3° and did not depress the m.p. of an authentic specimen.

Diethyllead di-m-bromobenzoate and triethyllead m-bromobenzoate from tetraethyllead (Method A). A solution of 37 g. (0.185 mole) of *m*-bromobenzoic acid and 60 g. (0.185 mole) of tetraethyllead in 100 cc. of ethanol and 100 cc. of benzene, together with a few granules of silica gel, was heated on the water-bath until the evolution of gas died down. After filtration from the silica, concentration to a volume of 60 cc., dilution with Skelly Solve B and cooling, a crystalline precipitate was obtained. The material was dissolved in benzene and then diluted with Skelly Solve B to incipient crystallization. After thorough cooling, a fraction of crystals melting with decomposition at 160–162° was obtained. The filtrate was diluted further with Skelly Solve B to yield an additional crop of crystals which melted at 100–102°.

TABLE III

TRIETHYLLEAD SALTS PREPARED BY METHOD B

NO.	TRIETHYLLEAD SALT	YIELD, %	M.P., °C.	Pb ANALYSIS Calc'd, %	Pb ANALYSIS Found, %
A	1-Amino-4-naphthalenesulfonate	20	238–240, dec. with evolution of foul odor.	40.14	40.17
B	2-Amino-5-toluenesulfonate[a]	22	210, dec.	43.15	42.92
C	*p*-Aminobenzoate monohydrate	46	84–86	46.03	46.06
C¹	*p*-Aminobenzoate anhydrate	—	Charred at 265 without melting.	48.17	48.31
D	*p*-Toluenesulfinate	44	86–88	46.13	48.71
E	Cyclohexylsulfinate	40.0	132–134	46.92	46.55
F	*p*-Tolylthiosulfonate	67.8	109	43.05	43.36
G	Selenocyanate	88–93	33–34	51.89	51.81 51.99
H	Thiocyanate	90–93	26.5–27	58.79	58.92 58.83

[a] No reaction took place between tetraethyllead and either an aqueous or an alcoholic solution of 2-amino-5-toluenesulfonic acid in the presence of silica gel. The reactants were heated on a water-bath for several hours.

The melting point of the less-soluble or higher-melting fraction was raised to 178–179° with decomposition, after two recrystallizations from methanol. The yield was 12 g. (9.8%). This was the diethyllead salt.

Anal. Calc'd for $C_{18}H_{18}Br_2O_4Pb$: Pb, 31.14. Found: Pb, 30.84.

The more-soluble or lower-melting fraction was twice recrystallized from benzene and Skelly Solve B to yield 2.8 g. (3.1%) of fine, white needles, melting at 112°. A mixture melting point with an authentic specimen prepared by method C (Table II) showed no depression.

Triethyllead salts from triethyllead acetate. Method B. Table III contains a list of triethyllead salts prepared from triethyllead acetate and the alkali salts of carboxylic, sulfonic, sulfinic, thiocyanic, and selenocyanic acids. An aqueous solution of the alkali salt was added to an aqueous solution of triethyllead acetate. Generally, the salt precipitated almost instantaneously, occasionally as an oil which quickly solidified to a crystalline mass. Only in the case of the triethyllead 2-amino-5-toluenesulfonate did the reaction solution have to be concentrated by an *in vacuo* distillation of the solvent before the salt separated out. Compound (A) was recrystallized from boiling ethanol, (B) from alcohol and ether, and (C) from benzene and Skelly Solve A. The anhydrous product of (C) was obtained by drying the monohydrate in a vacuum desiccator over conc'd sulfuric acid for 16 hours. Compounds (D) and (F) were recrystallized from benzene and Skelly Solve B, whereas (E) was analyzed without recrystallization. Compound (G) was recrystallized from a small amount of ethanol and water. The potassium selenocyanate used in the preparation of (G) was made by the method of Muthmann and Schröder (8). Compound (H) is insoluble in water and does not darken on exposure to light. These observations are in contrast to those of Klippel (9) who reported the preparation from triethyllead chloride and silver thiocyanate.

TABLE IV

POLY-TRIETHYLLEAD SALTS PREPARED BY METHOD C

NO.	NAME OF PRODUCT	YIELD, %	M.P., °C.	Pb ANALYSIS	
				Calc'd, %	Found, %
A	Di-triethyllead fumarate[a]	83	Began to decompose to an orange powder at 165.	59.00	59.13
B	Di-triethyllead adipate	83	Began to char at 190 but did not melt up to 360.	56.59	56.54
C	Di-triethyllead D-camphorate	71	Darkened to a tan powder at 175–190 but did not melt up to 310.	52.71	52.77
D	Tri-triethyllead citrate	92	Did not melt up to 350.	58.01	58.11

[a] The attempted preparation of di-triethyllead maleate from maleic acid and two equivalents of the base yielded a colloidal material which resisted various crystallization attempts.

Poly-triethyllead salts from triethyllead hydroxide. Method C. Table IV contains four poly-triethyllead salts prepared by method C, essentially according to the techniques employed for the compounds listed in Table I. Naturally, the triethyllead hydroxide used was equivalent to the number of acidic groups present in the polybasic acid. Compound (A) was recrystallized by dissolving in a small amount of ethanol and precipitating with ethyl ether. The product is readily soluble in ethanol and insoluble in water. Compound (B), which was recrystallized from ethanol, is soluble in warm ethanol and in dioxane, but insoluble in ether, ligroin or water. Compound (C) was obtained with fine, white needles from the reaction solution by dilution with water to incipient crystallization. Compound (D) was prepared by the dropwise addition of a solution of 0.96 g. (0.005 mole) of citric acid in 50 cc. of ethanol to a vigorously stirred solution of 6 g. (0.019 mole) of triethyllead hydroxide in 30 cc. of ethanol. After the reactants had been completely mixed, the solution remained clear for 2 to 3 minutes before a white, powdery precipitate began to settle out. The salt could not be crystallized because of its insolubility in the usual laboratory solvents and was, therefore, purified by trituration with ethanol and finally with ether.

Diethyllead di-p-toluate. When equimolar quantities of triethyllead hydroxide and *p*-toluic acid were reacted in alcoholic solution, the product was diethyllead di-*p*-toluate. In one experiment, the reaction solution was evaporated *in vacuo* over conc'd sulfuric acid, and in another poured on crushed ice. The crude product was recrystallized from a large volume of ether. The yield of pure product, melting with decomposition at 186°, was 30%.

Anal. Calc'd for $C_{20}H_{24}O_4Pb$: Pb, 38.64. Found: Pb, 38.37.

Diethyllead di-p-chlorobenzoate. To 2 g. (0.0127 mole) of *p*-chlorobenzoic acid in 20 cc. of ethanol and 10 cc. of dioxane was added 4 g. (0.0127 mole) of triethyllead hydroxide in 20 cc. of ethanol. The solution was diluted with water, whereupon an oil came down. The oil was re-dissolved by the addition of more ethanol and the solution was allowed to evaporate at room temperature and pressure. The residue, recrystallized from ethanol and a little water, melted at 185° with decomposition. The yield was 1.4 g. (24.4%).

Anal. Calc'd for $C_{18}H_{18}Cl_2O_4Pb$: Pb, 35.94. Found: Pb, 35.23.

The preparation of the triethyllead *p*-chlorobenzoate is reported in Table I.

Diethyllead di-nicotinate. To 2 g. (0.016 mole) of nicotinic acid in 10 cc. of ethanol was added 5 g. (0.016 mole) of the organolead base in 30 cc. of ethanol. The crystalline residue obtained after evaporation of the reaction solution at room temperature was triturated with acetone and filtered. The residue was recrystallized from ethanol. The yield of diethyllead salt, melting with decomposition at 143°, was 1.1 g. (26.6%).

Anal. Calc'd for $C_{16}H_{18}N_2O_4Pb \cdot H_2O$: Pb, 39.28. Found: Pb, 39.27.

Diethyllead di-N-n-butylanthranilate. A solution of 3 g. (0.016 mole) of the acid and 5 g. (0.016 mole) of the organolead base in 40 cc. of ethanol and 5 cc. of dioxane was evaporated to dryness at room temperature. The residue was recrystallized several times from an ethanol-water solution. The yield of the diethyllead salt, melting at 169–169.5° with decomposition, was 1.7 g. (32.7%).

Anal. Calc'd for $C_{26}H_{38}N_2O_4Pb \cdot H_2O$: Pb, 31.03. Found: Pb, 29.85.

Diethyllead selenite. To a solution of 15.5 g. (0.12 mole) of selenious acid (10) in 30 cc. of alcohol and 3 cc. of water was added 38.9 g. (0.12 mole) of tetraethyllead. The mixture was heated on a water-bath until the evolution of gas ceased. The fine, white crystalline precipitate was filtered off and washed with ethanol, water, ethanol, and ether in succession. The yield was 7.3 g. (15.5%). The compound, which did not melt up to 286°, was insoluble in ethanol, acetone, dioxane, carbon tetrachloride, propylene glycol, benzene, ether, and pyridine.

Anal. Calc'd for $C_4H_{10}O_3PbSe$: Pb, 52.83. Found: Pb, 52.29.

Triethyllead formate. Attempted preparations. The reaction between 5 g. of triethyllead hydroxide and one equivalent of 89% formic acid yielded lead formate, instead of the desired triethyllead formate.

Anal. Calc'd for $C_2H_2O_4Pb$: Pb, 69.75. Found: Pb, 70.33.

The warmed reaction between tetraethyllead and formic acid in the presence of silica gel produced a vigorous gas evolution and the simultaneous precipitation of beautiful, transparent crystals, which also analyzed for lead formate.

Anal. Found: Pb, 70.20.

Some attempted preparations. Method A. Little or no reaction occurred between tetraethyllead and (a) cyanoacetic acid in ethanol, (b) 3-quinolinecarboxylic acid without a solvent, and (c) phenylhydrazine *p*-sulfonic acid suspended in ethanol. The reactants were heated with silica gel on a water-bath for 3 to 5 hours.

Method B. No organolead salt could be prepared from triethyllead acetate and (a) sodium α-bromo-π-D-camphorsulfonate (11), (b) sodium α-bromo-β-camphorsulfonate, or (c) sodium *p*-selenocyanobenzenesulfonic acid.

Method C. No derivative could be obtained from the attempted reaction between triethyllead hydroxide and D-camphor oxime in ethanol. The oxime was recovered in 90% yield.

Triethyllead ethoxide. An alcoholic solution of sodium ethoxide was added dropwise to a well-stirred solution of triethyllead chloride (12) in ethanol. Sodium chloride precipitated in 94.5% yield. Removal of the solvent by an *in vacuo* distillation yielded a colorless oil which darkened and solidified to a crystalline mass on cooling. The latter was unstable to air and was considered unsuitable for analysis.

Triethyl-β-chloroethyllead. Attempted preparation. In an inert atmosphere of nitrogen 11.2 g. (0.048 mole) of β-chloroethyl *p*-toluenesulfonate in 40 cc. of ether was added dropwise over a 30 minute period to a well-stirred solution of 0.048 mole of triethylleadsodium (13) in 300 cc. of ether. A copious white precipitate formed. Toward the end of the addition, the yellow color of the triethylleadsodium solution disappeared. The contents were hydrolyzed and the yellow ether layer was dried over calcium chloride. After filtration, the ether was removed by distillation under the reduced pressure of the water pump. As the ether layer was concentrated, a white precipitate settled out. This did not melt up to 280° and may be di-triethyllead oxide as indicated by its analysis for lead.

Anal. Calc'd for $C_{12}H_{30}OPb_2$: Pb, 68.53. Found: Pb, 69.14.

After removing the above solid by filtration, the filtrate was subjected to distillation in a nitrogen atmosphere at less than one mm. At a bath temperature of 85°, decomposition began to take place with the deposition of lead. A minute quantity of liquid, which managed to distill over before decomposition was complete, contained lead but no halogen.

It may be that the reaction between triethylleadsodium and β-chloroethyl *p*-toluenesulfonate yields some triethyllead, of which a part on standing is converted to the oxide. The remainder on distillation probably undergoes the following reaction: $(C_2H_5)_3Pb \rightarrow (C_2H_5)_4Pb + Pb$.

DISCUSSION

The suggested relationship between acid strength and the degree of alkyl-lead cleavage has already been mentioned. The relationship is without foundation, as Browne and Reid (1) have prepared a large number of triethyllead salts from acids showing a 20,000 fold variation in acidity — from pelargonic acid ($K_1 = 1.0 \times 10^{-5}$) (14) to trichloroacetic acid ($K_1 = 2.0 \times 10^{-1}$) (15). The effect of the solvent, on the other hand, is probably the most important influence noted to date. This effect has been observed in the reactions between tetraethyllead and *m*-nitrobenzoic acid in ethanol (single cleavage) and in benzene (double cleavage). In a mixture of ethanol and benzene, *m*-bromobenzoic acid yields products derived from both single and double carbon-lead cleavage. The solvent influence has also been observed in the reaction of triethyllead hydroxide with *p*-chlorobenzoic acid which forms triethyllead *p*-chlorobenzoate in ethanol and the diethyllead di-*p*-chlorobenzoate in an ethanol-dioxane solvent.

Furthermore, a direct relationship between acidity and alkyl-lead cleavage infers a mechanism of acid ionization, followed by proton attack on the tetraalkyllead. Accordingly, one could expect double cleavage in the strongly polar ethanol and single cleavage in the weakly polar benzene or dioxane. The reverse is the case. Also, since ethanol and benzene have almost identical boiling points, the influence of temperature must be of little or no import, except, of course, in the hot benzene recrystallization of a triethyllead salt, which could lead to further transformation to the diethyllead derivative.

Contrary to previous reports (1, 2), the melting points of the organolead salts do not show any more appreciable variation with the rate of heating than those exhibited by most organic compounds. The simplicity of preparation, especially by methods B and C, suggests the usefulness of these salts as identification derivatives. Also, the high molecular weights of the derivatives suggest the possibility of application to the quantitative determinations of various types of acidic compounds. Stock supplies of triethyllead acetate and triethyllead hydroxide may be kept for months without appreciable decomposition. A derivatization is a matter of minutes, involving weighing, dissolving, mixing and a filtration. Water is the solvent for method B, which is admirably suited for the reaction with the salts of sulfonic, sulfinic, and carboxylic acids. If the acid is unknown, the aqueous solution obtained from the neutralization equivalent may be utilized for the derivatization by simply adding an aqueous solution of the calculated amount of triethyllead acetate. The recommended solvent for method C is ethanol since it is least conducive to side or secondary reactions. Dilution with water will precipitate the derivative. Recrystallization should be effected by dissolving in ethanol, filtering from any insoluble matter, and diluting with water to incipient crystallization.

SUMMARY

The preparation of a variety of triethyllead compounds derived from mono- and poly-basic acids is described. Most of these compounds were sternutators. A few diethyllead compounds were also prepared, but none of these exhibited sternutatory activity.

The effect of solvent on the extent of alkyl-lead cleavage in the R_4Pb or the R_3PbOH type of structure was demonstrated.

The usefulness of the organolead salts in the identification of carboxylic, sulfonic, sulfinic, sulfonamide, and related acidic compounds is pointed out.

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