United States Patent

Prentice

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[45] **June 13, 1972**

[54] **ETHANECARBONYL-1,2-DIPHOSPHONIC ACID, WATER-SOLUBLE SALTS THEREOF AND PROCESS FOR PREPARATION**

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[52] **U.S. Cl.**.....**260/502.4 P,** 260/253, 260/284, 260/285, 260/286 R, 260/289 R, 260/290 R, 260/291, 260/292, 260/293.56, 260/293.8, 260/298, 260/309, 260/429.9, 260/430, 260/435 R, 260/444, 260/501.19, 260/501.21

[51] **Int. Cl.**.....**C07f 9/38,** C11d 3/36

[58] **Field of Search**.....260/502.4 A, 502.4 P, 501.19, 260/501.21, 253, 284, 285, 286 R, 289 R, 290 R, 291, 292, 293.56, 293.8, 298, 309, 429.9, 430, 435 R, 444

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[57] **ABSTRACT**

A process for preparing ethane carbonyl-1,2-diphosphonates which comprises reacting 2-haloethane-1-hydroxy-1,1-diphosphonic acid with at least 3 equivalents of a base having a pK_b up to about 10. This process yields a salt of ethane carbonyl-1,2-diphosphonic acid which can be converted to the free acid.

9 Claims, No Drawings

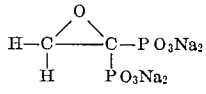
ETHANECARBONYL-1,2-DIPHOSPHONIC ACID, WATER-SOLUBLE SALTS THEREOF AND PROCESS FOR PREPARATION

FIELD OF THE INVENTION

The present invention relates to organo-phosphorus compounds which are ethane carbonyl-1,2-diphosphonates. Members of this new class of compounds are distinguished by being relatively stable 1-ketophosphonates. This unique relative stability allows them to be used as valuable intermediates in the preparation of ethane hydroxy triphosphonate builder compounds.

SUMMARY OF THE INVENTION

The compounds of the present invention are prepared by a reaction between haloethane-1-hydroxy-1,1-diphosphonic acid and at least 3 equivalents of a base having a pK_b up to about 10. It is believed that the reaction proceeds through and is made possible by the formation of an intermediate reaction product which is an epoxide reaction product believed to have the formula

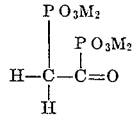


which rearranges to form ethane carbonyl-1,2-diphosphonates.

DETAILED DESCRIPTION

This invention pertains to organophosphorus compounds and to a process for their preparation.

The compounds have the formula



in which each M is hydrogen or a cation forming a water-soluble salt. M, for example, can be sodium, potassium, lithium, ammonium, alkyl amine having one to about four carbons per each alkyl group, or alkanolammonium having one to four carbons per each alkanol group.

Specific examples of compounds provided by the present invention are: ethane carbonyl-1,2-diphosphonic acid; monosodium ethane carbonyl-1,2-diphosphonate; disodium ethane carbonyl-1,2-diphosphonate; trisodium ethane carbonyl-1,2-diphosphonate; tetrasodium ethane carbonyl-1,2-diphosphonate; and the corresponding potassium, lithium and ammonium salts. Others are alkylamine compounds such as mono-, di-, and tri- , alkylamines, e.g., di(trimethylamine)ethane carbonyl-1,2-diphosphonate, and mono(diethanolamine)ethane carbonyl-1,2-diphosphonate. Further examples are tetraalkylammonium ethane carbonyl-1,2-diphosphonate, e.g., tetraethylammonium ethane carbonyl-1,2-diphosphonate.

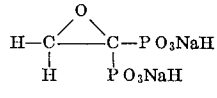
The compounds of the present invention are especially useful and valuable as starting materials for the preparation of a highly effective class of detergency builder compounds, i.e., ethane-1-hydroxy-1,1,2-triphosphonate. Such builders are the subject of U.S. Pat. No. 3,400,148. A process for converting the compounds of the present invention to the triphosphonate builder is the subject of a copending, commonly assigned patent application Ser. No. 780,370, filed concurrently herewith by James B. Prentice as "Process For Preparation Of Ethane-1-Hydroxy-1,1,2-Triphosphonates From Ethanecarbonyl Diphosphonates."

The process embodiment of the present invention comprises reacting 1 mole of 2-haloethane-1-hydroxy-1,1-diphosphonic acid with at least 3 moles of a base having a pK_b up to about 10, preferably less than 8, in an aqueous solution.

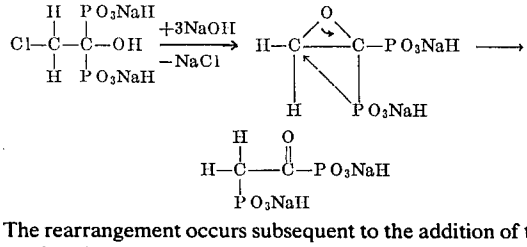
The halo-substituent can be chlorine, bromine or fluorine. Chlorine and bromine are preferred. The chloro-compound is referred to frequently below as being a representative embodiment of this invention. The result of this reaction is a formation of a tetra salt of ethane carbonyl-1,2-diphosphonic acid. The specific salt formed is determined by the particular base selected as a reactant. Any base compound can be used which has a pK_b up to about 10, and preferably less than 8. The base strength appears to be the only limiting factor in the selection of a particular base. As a result, the base can be an inorganic or organic base compound with inorganic bases being preferred. Illustrative inorganic base compounds are sodium, potassium, lithium, calcium, barium, magnesium, ammonium, and silver hydroxides, carbonates, bicarbonates, and acetates, arsenous oxide, lead hydroxide and zinc hydroxide. Preferred are sodium, potassium, lithium and ammonium hydroxides. Illustrative organic bases are aconitine, ammonium hydroxide, isoamylamine, aniline, apomorphine, benzylamine, benzidine, brucine, n-butylamine, iso-butylamine, sec-butylamine, tert-butylamine, caffeine, cinchonidine, cinchonine, cocaine, codeine, coniine, di-iso-amylamine, di-iso-butylamine, diethylamine, diethylbenzylamine, dimethylamine, dimethylaminoantipyrine, dimethylbenzylamine, dipropylamine, emetine, ethanolamine, ethylamine, ethylenediamine, hydrastine, hydrazine, hydroquinine, hydroxylamine, o-methoxybenzylamine, m-methoxybenzylamine, p-methoxybenzylamine, N,N-methoxybenzylamine, methylamine, o-methylbenzylamine, m-methylbenzylamine, p-methylbenzylamine, N,N-methylbenzylamine, methyldiethylamine, morphine, β-naphthylamine, narcotine, nicotine, novocain, papaverine, p-phenetidine, ϵ-phenylamylamine, δ-phenylbutylamine, o-phenylenediamine, p-phenylenediamine, β-phenylethylamine, β-phenylethyl-methylamine, phenylhydrazine, γ-phenylpropylamine, N,N-iso-propylbenzylamine, physostigmine, pilocarpine, piperazine, piperidine, n-propylamine, iso-propylamine, pyridine, quinidine, quinine, quinoline, solanine, sparteine, strychnine, tetramethylenediamine, thebaine, o-toluidine, m-toluidine, p-toluidine, tri-iso-butylamine, triethylamine, trimethylamine, trimethylenediamine, tripropylamine, and veratrine.

The reaction occurs at a temperature in the range of 20° F. to about 215° F., and preferably should be performed in the range of 30° F. to about 215° F.

While the mechanism of the reaction is not fully understood, it is believed that it proceeds through the formation of an intermediate epoxy compound having the following general formula in which sodium has been arbitrarily selected as the cation.



It is believed that this intermediate epoxy compound then undergoes rearrangement by having one of the phosphonate groups migrate to the adjacent carbon atom with an accompanying cleavage of the oxirane ring. This is illustrated emperically in the following equation, again using sodium as a representative cation and sodium hydroxide as a base: (The dotted lines show migration pattern.)



The rearrangement occurs subsequent to the addition of the second mole equivalent of base. It is fairly certain, however,

that the rearrangement does not begin with the addition of the first or second base cations for these have been noted in a titration curve. Presumably, therefore, the phosphonate group migrates and the oxirane ring cleaves upon the addition of the third or fourth base cation, e.g., sodium and the like.

In any event, it is unexpected that the reaction does produce as its final product an ethane carbonyl-1,2-diphosphonate compound. The reaction is very rapid with almost quantitative yields, i.e., on the order of 95–100 percent of the total starting phosphorus as the carbonyl diphosphonate. The resulting ethane carbonyl-1,2-diphosphonate salt is readily converted to a free acid or a partial salt by addition of a strong acid such as HCl, H_2SO_4, HNO_3 and the like. The salt can also be ion exchanged in any convenient manner such as passing the salt through a cation exchange resin in the H^+ form.

The reaction is run in an aqueous solution. While there is no need for an additional solvent, one can be used. Aqueous solutions in the range of 2 percent to about 50 percent of haloethane carbonyl diphosphonate and 2 to 50 percent of the base reactant are used. Solid sodium hydroxide can likewise be used as illustrated below.

This reaction can be seen also to be a dehydrohalogenation of the starting chloroethane-1-hydroxy-1,1-diphosphonic acid. As a result, salt formation such as 1 mole of NaCl is compensated for by the addition of an equivalent amount of base.

A preferred embodiment of the present invention is to add the base to an aqueous solution of the chloroethane-1-hydroxy-1,1-diphosphonic acid. If this order is reversed, the desired reaction still occurs but with a considerable amount of an undesired side product being formed.

To a lesser degree, the undesired side product also tends to form when more than four equivalents of the base are added rapidly to an aqueous chloroethane-1-hydroxy-1,1-diphosphonic acid. Consequently the preferred practice is to add the base slowly to an aqueous solution of chloroethane-1-hydroxy-1,1-diphosphonic acid with good stirring.

As noted, the reaction including the rearrangement step takes from a few seconds to about 6 hours. The reaction is usually completed within 5 minutes if 4 or more moles of base are added. A preferred range in which to practice this process is from a few seconds to about 2½ hours.

It is apparent to one skilled in the art that the addition of the number equivalents of the base can be varied to take into consideration a desired production level or reaction system or technique. Such permissible variations include the use of different bases to partially titrate to a given salt form and then to complete the reaction with a different base.

In this respect, a preferred recovery procedure involves practicing the present invention by converting chloroethane-1-hydroxy-1,1-diphosphonic acid to a monosodium salt form by reacting it with an alkali metal ion preferably sodium acetate, sodium hydroxide, sodium oxide, sodium carbonate, or sodium bicarbonate, in the presence of an organic solvent. Preferably the organic solvent is acetic acid and the alkali is added as sodium acetate. This reaction proceeds at a temperature of 30° F. to 300° F. and preferably 50° F. to about 275° F. The amount of alkali metal added should be in the range of 0.5 to 1.1 moles of alkali metal ion per mole of chloroethane-1-hydroxy-1,1-diphosphonic acid. The amount of organic solvent, preferably acetic acid, present is not critical. It serves only as a solvent and can satisfactorily be employed in an amount per mole of chloroethane-1-hydroxy-1,1-diphosphonic acid of 3 to about 50 moles of solvent, preferably 6 to 15 moles of solvent per diphosphonic acid. A more detailed description of this separation technique is found in copending U.S. application Ser. No. 623,211 filed Mar. 15, 1967, by Pflaumer et al. as "A Process For Separating Ethane-1-Hydroxy-1,1-Diphosphonic Acid From A Solution Of It With Orthophosphoric Acid" and now abandoned. The basis for this preferred procedure is the discovery that the monosodium salt crystallized much more rapidly from an organic system than it does from an aqueous system. Thus, a purer product can be obtained by practicing the preferred method rather than by crystallizing the monosodium salt from any aqueous system, although satisfactory results are obtained either way.

The recovered monosodium salt is then reacted with four more equivalents of a suitable base, e.g., sodium hydroxide, and the heretofore-described rearrangement occurs to form the tetrasodium salt of ethane carbonyl-1,2-diphosphonate.

The dehydrohalogenation of the starting chloroethane-1-hydroxy -1,1-diphosphonic acid occurs readily in an aqueous base solution. The rate of chlorine removal as HCl is considerably dependent on pH, beginning at about pH 5.5 and increasing with increasing pH. If chloroethane-1-hydroxy-1,1-diphosphonic acid was stable at high pH, the expected titration curve would have endpoints at two, three and four equivalents of base. The titration curves which have been obtained, however, reveal that none of the HCl has been removed at the first endpoint (2 equivalents), while all of the HCl has been removed by the time the last endpoint (5 equivalents) is reached. This is true regardless of the rate of titration. The large difference in the amount of base required to reach the second endpoint (3.16 of 4.00 equivalents) demonstrates the lower rate of HCl removal in the near neutral pH range, The removal of HCl from chloroethane-1-hydroxy-1,1-diphosphonic acid has also been substantiated by silver nitrate titration for chloride ion. At the second equivalence point no free chloride ion can be detected while in 1 minute the pH 10, the theoretical amount of chloride ion, is present in aqueous solutions.

Certain by-products can be formed by the present reaction. It has been clearly demonstrated, however, that the migration of the phosphonate group to the alpha carbon to form ethanecarbonyl-1,2-diphosphonate (ECnDP) predominates in this system. It is difficult to determine precisely the chemical composition of the reaction by-products. It is known, however, that once they are formed the reaction by-products are stable toward changes in temperature and pH. The possible formation of unknown side product or side products can readily be prevented according to the present invention. One way of accomplishing this is by using concentrated solutions of chloroethane-1-hydroxy-1,1-diphosphonic acid neutralized with sodium hydroxide provided that the number of moles of base is not excessive. The impurities also can be substantially completely avoided by adding the base reactant more slowly or by reducing the total moles of base so that more of the dehydrohalogenation and rearrangement can occur at a lower pH. The ethanecarbonyl-1,2- diphosphonic acid compound formed by the foregoing reaction can be crystallized as the fully neutralized salt, e.g., sodium, potassium, ammonium and the like. It is recovered in this way in the form of monohydrate salt or an anhydrous acid. The fully neutralized salts are readily precipitated from aqueous solutions as well-formed hydrated crystals. The free acid is slower to crystallize but can be obtained as either the monohydrate from concentrated aqueous solutions or as the anhydrous acid crystallized from acetic acid solution. The free ethanecarbonyl-1,2-diphosphonic acid is surprisingly much more stable toward hydrolysis than would be expected judging from the known instability of 1-ketophosphonates, as described in *Organo-Phosphorus Compounds by G. M. Kosolapoff; Wiley*, 1950, page 139.

The ethanecarbonyl-1,2-diphosphonic acid has been found to be stable in aqueous solutions for 2–3 hours at 70° C. At 100° C. after 48 hours, the free acid was completely decomposed.

The present invention is more fully illustrated by the following specific examples. These are presented to provide a fuller understanding of the present invention. The present invention is not intended to be limited to the following procedures since numerous variations and modifications thereof will be apparent to those skilled in the art.

Preparation of Ethanecarbonyl-1,2-Diphosphonate From Chloroethane-1-Hydroxy-1,1-Diphosphonate

In each of the following examples, the solution was analyzed by $P^{31}MR$ spectra. The results are given as the percent of the total phosphorus which was in the form of ECnDP, ethane carbonyl-1,2-diphosphonate. In each case most of the remainder was present as an unidentified compound, having a chemical shift of 2 = −13.5 ppm in the $P^{31}MR$ spectrum (relative to 85% H_3PO_4 reference).

EXAMPLE I

1.32 g. (0.005 mole) of the NaH_3 salt of chloroethane-1-hydroxy-1,1-diphosphonic acid (ClEHDP) was dissolved in 2.8 cc. of water and 1.20 cc. (0.015 mole) of 33-⅓ weight percent NaOH was added slowly with good stirring. An ice bath was applied during addition of the NaOH so that the reaction temperature did not exceed 20° C. The clear aqueous reaction solution on analysis was found to contain 96 percent of the product as ethanecarbonyl-1,2-diphosphonate (trisodium salt).

EXAMPLE II

Same procedure as in Example I was followed except that 1.60 cc. (0.02 mole) of 33-⅓ % NaOH were used, and 2.40 cc. of water were present to dissolve the chloroethane-1-hydroxy-1,1-diphosphonate. The clear aqueous reaction solution on analysis was found to contain 71 percent ethanecarbonyl-1,2-diphosphonate (tetrasodium salt)

EXAMPLE III

Same procedure as Example I was followed except that 2.00 cc. (0.025 mole) of 33-⅓ % NaOH were used, and 2.00 cc. of water were present to dissolve the chloroethane-1-hydroxy-1,1-diphosphonate. The clear aqueous reaction solution on analysis was found to contain 70 percent ethanecarbonyl-1,2-diphosphonate (tetrasodium salt).

EXAMPLE IV

1.32 g. (.005 mole) of the NaH_3 salt of chloroethane-1-hydroxy-1,1-diphosphonic acid was dissolved in 1.32 cc. of water and 2.00 cc. of 12.5 N NaOH (0.03 mole) was added with good stirring. An ice bath was used to prevent the solution temperature from exceeding 20° C. The clear solution product was assayed by $P^{31}MR$ analysis and found to contain 70 percent ethanecarbonyl-1,2-diphosphonate (tetrasodium salt).

EXAMPLE V

Same procedure as in Example IV was followed except that 2.87 cc. H_2O were used to dissolve the chloroethane-1-hydroxy-1,1-diphosphonate. Analysis showed the reaction solution to contain 73 percent ethanecarbonyl-1,2-diphosphonate (tetrasodium salt).

EXAMPLE VI

Same procedure as in Example IV was followed except that 11.85 cc. H_2O were used to dissolve the chloroethane-1hydroxy-1,1-diphosphonate. Analysis showed the reaction solution to contain 81 percent ethanecarbonyl-1,2-diphosphonate (tetrasodium salt).

The starting chloroethane-1-hydroxy-1,1-diphosphonate reactant used in the present invention can be prepared in any convenient manner. The following demonstration is given by way of example.

Preparation of monoammonium salt of chloroethane-1-hydroxy-1,1-diphosphonate

Chloroacetic acid (1,250 g., 12 moles), phosphorus acid (147 g., 1.8 moles), and phosphorous trichloride (212 cc., 2.3 moles), are heated to 105° C. over a 2-hour period, and the temperature maintained an additional 2 hours. At this point 200 cc. of water are added, and the temperature maintained at 60° C. for 16 hours. To the clear solution 154 g. NH_4OOCCH_3 (ammonium acetate) dissolved in 800 cc. of acetic acid is added. The monoammonium salt of chloroethane-1-hydroxy-1,1-diphosphonate precipitates on standing, and is subsequently filtered and washed with acetic acid, followed by ethyl ether and dried. The yield is about 372 g. or 63 percent of the theoretical chloroethane-1-hydroxy-1,1-diphosphonate (NH_4H_2 salt), monoammonium salt (NH_4H_3) of chloroethane-1-hydroxy-1,1-diphosphonic acid.

As noted above, the compounds of the present invention are useful starting materials for the preparation of a valuable class of detergency builders, i.e., ethane-1-hydroxy-1,1,2-triphosphonates. U.S. Pat. No. 3,400,148 relates to built detergent compositions in which such triphosphonate compounds are employed as builders. The following procedure illustrates the conversion of ethanecarbonyl-1,2-diphosphonates (ECnDP) to ethane-1-hydroxy-1,1,2-triphosphonates (EHTP). This procedure is more fully described and exemplified in the aforementioned commonly assigned copending U.S. Pat. application Ser. No. 786,370, concurrently filed by James B. Prentice as "Process For Preparation of Ethane-1-Hydroxy-1,1,2-Triphosphonates From Ethanecarbonyl-1,2-Diphosphonates."

preparation of ethane-1-hydroxy-1,1,2-triphosphonates from ethanecarbonyl-1,2-diphosphonate

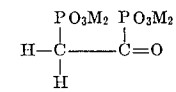
The free acid of ethanecarbonyl-1,2-diphosphonate·$1H_2O$ (4.46 g; 0.02 mole) was slurried in 18 cc. of Pr_2SO_2 and PCl_3 (1.9 cc.; 0.022 mole) was added at 29° C. The slurry quickly resolved to two liquid phases and the temperature rose to 35° C. The reaction mixture was heated slowly to 90° C. over a 1½ hour period. The reaction mixture had formed white solids at this point. The slurry was digested for 3 hours at 90° C. then filtered. The solids were washed with ethyl ether and dried under nitrogen. (Yield 6.8 g. of dry solids.)

The solid was identified as the condensate of ethane-1-hydroxy-1,1,2-triphosphonic acid by NMR and by an X-ray diffraction pattern.

The foregoing description of the present invention has been presented describing certain operable and preferred embodiments. It is not intended that the invention should be so limited since variations and modifications thereof will be obvious to those skilled in the art, all of which are within the spirit and scope of this invention.

What is claimed is:

1. A compound of the formula



in which each M is independently selected from the group consisting of hydrogen, sodium, lithium, potassium, ammonium, alkylamine having one to about four carbons per each alkyl group, and alkanolammonium having one to about four carbons per each alkanol group.

2. Ethanecarbonyl-1,2-diphosphonic acid.

3. Alkali metal salts of ethanecarbonyl-1,2-diphosphonic acid.

4. A process for the preparation of ethanecarbonyl-1,2-diphosphonate which comprises reacting a 2-haloethane-1-hydroxy-1,1-diphosphonic acid selected from the group consisting of 2-chloroethane-1-hydroxy-1,1-diphosphonic acid, 2-bromoethane-1-hydroxy-1,1-diphosphonic acid and 2-fluoroethane-1-hydroxy-1,1-diphosphonic acid with at least 3 mole equivalents of a base having a pK_b up to about 10 in an aqueous solution at a temperature in the range of from 20° F. to about 215° F.

5. A process according to claim 4 in which the reaction temperature is from about 30° F. to about 215° F.

6. A process according to claim 4 in which the 2-haloethane-1-hydroxy-1,1-diphosphonic acid is 2-chloroethane-1-hydroxy-1,1-diphosphonic acid.

7. A process according to claim 4 in which the reaction is performed by adding said base to said 2-haloethane-1-hydroxy-1,1-diphosphonic acid.

8. A process according to claim 4 in which said base is an inorganic base.

9. A process according to claim 8 in which the inorganic base is sodium hydroxide, lithium hydroxide, potassium hydroxide or ammonium hydroxide.

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