

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN THE PREPARATION OF THIOHYDROXIMATE CARBAMATES

(71) We, E. I. DU PONT DE NEMOURS AND COMPANY, a corporation organized and existing under the laws of the State of Delaware, United States of America, located at Wilmington, State of Delaware, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to improvements in a method of preparing thiohydroximate carbamates. More particularly it relates to a method of preparing S-alkyl thiohydroximate carbamates.

Organic chemical reactions at temperatures below the melting point of at least one of the reactants usually must be carried out in liquid solvent systems, in order to obtain reasonably fast, complete reaction with a minimum of by-products. The solvent system provides a molecular or near-molecular dispersion of the solid reactant(s) and also provides mobility for the molecules. Thus, each molecule is accessible and free to travel, and can meet and react quickly with molecules of the other reactant(s).

In contrast, when a solid-state reaction system is used, only the surface molecules of the solid reactant(s) are accessible for reaction, unless one reactant is capable of diffusing into the particles of the other reactant. Even in the latter case, solid-state systems are generally unsatisfactory for conducting reactions on a commercial scale because reaction rates are diffusion-controlled and slow compared to solvent system reactions, and because the reaction product may block the internal and external surfaces on which it is formed, thereby preventing access to molecules of the solid reactant, and causing the reaction to slow down or stop. Also, high local concentrations of reactants occur, resulting in the formation of unwanted by-products.

Some of these problems of a solid-state reaction systems are illustrated by the work of Pinero et al, reported in *Ind. Eng. Chemistry Process Des. Develop.*, Vol. 10, No. 4, pp. 476—482, Oct. 1971. The article describes experimental work on the kinetics of a solid-state reaction between sulfathiazole and succinic anhydride. In this work compression at 1000 Kg./cm.² was used to get good contact of reactants. Nevertheless, stoppage of the reaction before completion because of plugging of access to reactive surfaces was reported, and the highest conversions shown were only 80%.

Reaction between solid S-alkyl thiohydroximates and methyl isocyanate to produce S-alkyl thiohydroximate carbamates has heretofore been carried out only in liquid solvent systems. In addition, S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate has heretofore been prepared only at temperatures substantially below both its melting point (approximately 78°C.) and the melting point of its most convenient precursor, S-methyl N-hydroxythioacetimidate (approximately 93°C.).

In U.S. Patent No. 3,506,698, there is disclosed a process for making S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate by reacting methyl isocyanate with an aqueous slurry of S-methyl N-hydroxythioacetimidate. At no time during this process is the temperature permitted to rise higher than 55°C. And, in U.S. Patent No. 3,576,834, there is disclosed the same reaction being conducted in a methylene chloride solution. At no time during the course of this reaction is the temperature permitted to rise higher than 32°C. U.S. Patent 3,560,55 and U.S. Patent 3,530,222 teach the reaction of S-methyl 1 - (dimethylcarbamoyl) - thioformhydroximate with methyl isocyanate to produce S-methyl 1 - (dimethylcarbamoyl) - N - [(methylcarbamoyl)oxy] - thioformimidate in acetone solution.

While a solvent system reaction of methyl

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isocyanate and S-alkyl thiohydroximates is reasonably rapid and complete, there are a number of disadvantages in the use of a solvent system reaction. Such a procedure is complex and the use of a solvent necessitates the use of numerous and expensive processing steps and equipment. The solvent must be stored; it must be introduced and maintained in the system in proper quantity and purity; it must be removed from the system as by distillation and disposed of or returned for further storage. The end product must be crystallized and centrifuged or filtered and then dried. These steps increase the cost and complexity of the process.

It has now been found that fast reaction, high quality, and excellent yields can be achieved in these reactions in the absence of a solvent and in the absence of a continuous liquid phase by addition of the methyl isocyanate to an agitated bed of solid particles of the S-alkyl thiohydroximate. This was surprising because of the difficulties normally encountered with solid-state reaction systems, which lead to slow reaction, low yield, and the formation of undesired by-products.

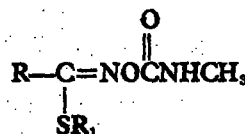
It has further been found that addition advantages can be achieved in the solventless process for producing S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate by permitting the temperature of the reaction mass to rise sufficiently to maintain the reaction mass as a continuous liquid phase for at least a terminal portion of the reaction.

The relatively high temperatures generally required to bring organic materials to a molten state would normally preclude an effective, efficient, and complete reaction of such materials producing high quality and high yield of the desired product. Temperatures high enough to melt the reactants will normally produce side reactions and significant amounts of by-products thus decreasing the yield and quality of the desired product. Such temperatures are likely to cause significant decomposition of both the starting materials and the finished products. For example, a temperature of approximately 100°C. is sufficient to completely decompose a sample of purified (recrystallized) S-methyl N-hydroxythioacetimidate within only 30 minutes.

It has now been found that S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate can be produced in a solvent-less reaction while maintaining the reaction mass as a continuous liquid phase for at least a terminal portion of the reaction, thus eliminating or diminishing the disadvantages discussed above in connection with solvent reactions and maintaining the advantages normally associated with performing a reaction in a solvent system, for example, ease of assuring complete intermixture of the reactants, ease of maintaining absence of temperature gradients or hot spots in the reaction mass, faster and more com-

plete reaction, and ease of physical handling of reactants and reaction products, while avoiding significant side reactions, or significant decomposition of the reactants or reaction products. This is accomplished by careful control of operating conditions and results in a fast, complete reaction which produces high quality and high yields of the reaction product.

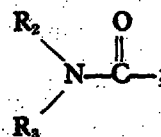
Accordingly, this invention provides a process for the preparation of S-alkyl thiohydroximate carbamates of the formula:



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wherein

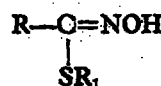
R is methyl, ethyl, or



R₁ is methyl, ethyl, n-propyl, or isopropyl; R₂ is hydrogen, methyl, ethyl, n-propyl, or isopropyl; and

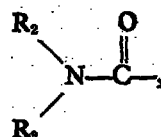
R₃ is hydrogen or methyl, provided that when R₂ is ethyl, n-propyl or isopropyl, R₃ is hydrogen;

in which methyl isocyanate is reacted with an S-alkyl thiohydroximate of the formula:



II

wherein R and R₁ are as defined above, the reaction being carried out (a) at least in part, by adding the methyl isocyanate, in gaseous or liquid form, to an agitated bed of solid particles of the S-alkyl thiohydroximate in the absence of a continuous liquid phase, a catalyst being present when R represents the group



while removing the heat of reaction, the rates of isocyanate addition and heat removal being balanced so as to maintain the temperature of the reaction mass at or above 0°C. but below the melting points of the starting thiohydroximate, and the thiohydroximate car-

5 bamate finished product, and/or (b) by contacting the reactants, in the case where R and R₁ are both methyl in the absence of a solvent under conditions such that for at least a terminal portion of the reaction, the reaction mass is maintained as a continuous liquid phase. The preferred temperature in (a) is from 25°C to below the temperature at which the reaction mass becomes tacky.

10 This improved process provides the products of formula I in high yield and quality in acceptable reaction times, without the investment required to conduct solvent reactions.

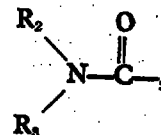
15 With respect to the method for making S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate (compound of formula I, above, where both R and R₁ are methyl), the process may comprise, as indicated above, carrying out the reaction between the methyl isocyanate and the S-methyl N-hydroxythioacetimidate under conditions such that the reaction mass is maintained as a continuous liquid phase for at least a terminal portion of the reaction. A continuous liquid phase includes a liquid with solids suspended therein as well as a liquid without such suspended solids. What is necessary to maintain a continuous liquid phase is that there not be such a high proportion of solids that the liquid phase becomes interrupted, i.e., not continuous. With respect to mixtures of the precursor and product thioacetimidates of the present invention, a continuous liquid phase has been found to exist in such mixtures containing as much as 75% (by weight) solids.

35 The above-mentioned reaction is exothermic and care must be taken to prevent excessive temperatures which may result in side reactions and the production of undesirably by-products or decomposition of the reactants or reaction products. Accordingly, it is generally desirable to run the reaction (b) at as low a temperature as possible while maintaining the reaction mass as a continuous liquid phase for at least a terminal portion of the reaction. The lowest temperature at which the reaction mass will be a continuous liquid phase will vary depending upon the quantity of precursor thioacetimidate present in the reaction mass, the quantity of product thioacetimidate present in the reaction mass, the quantity of unreacted or excess methyl isocyanate present in the reaction mass, and the quantity of impurities present in the reaction mass. In addition, since the reaction is sufficiently fast, high temperatures can be tolerated for short periods of time before the degree of side reaction or the degree of product and reactant decomposition becomes significant. Nevertheless, as a practical matter, the rates of isocyanate addition and heat removal are balanced so as to maintain the temperature of the reaction mass between 35° and 120°C.

65 This improved process produces S-methyl

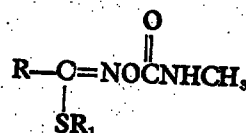
N - [(methylcarbamoyl)oxy]thioacetimidate more rapidly and in higher yields than the solid-state process described above, and without the investment required to conduct solvent reactions.

70 Thus, S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate can be produced by either a solid-state process or a continuous liquid phase process, as described above, or by a combination of the two. For practical purposes, other compounds of formula I (i.e., where R and/or R₁ are not methyl) are not produced by the continuous liquid phase process described above. More specifically, with respect to compounds of formula I where R is



decomposition of the reactants or reaction products occurs to such an extent as to outweigh the advantages gained by operating the reaction with the reaction mass maintained as a continuous liquid phase.

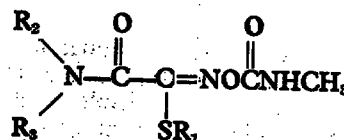
85 Melting points for several of the thiohydroximate carbamates of formula I are listed in the following tables:



(A)

R	R ₁	m.p. °C.
CH ₃	CH ₃	79—80
CH ₃	C ₂ H ₅	61—62
CH ₃	iso-C ₂ H ₅	60.5—61.5
C ₂ H ₅	CH ₃	44
C ₂ H ₅	C ₂ H ₅	56.5—57.5

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(B)

R ₁	R ₂	R ₃	m.p. °C.
CH ₃	H	H	176—177
CH ₃	CH ₃	H	112—113
CH ₃	C ₂ H ₅	H	125—127
CH ₃	n-C ₂ H ₅	H	87—88
CH ₃	i-C ₂ H ₅	H	140—142
CH ₃	CH ₃	CH ₃	101—102
C ₂ H ₅	H	H	156—157
C ₂ H ₅	CH ₃	CH ₃	61—63

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All of the precursor thiohydroximates for the above compounds are solids at 25°C.

The improved process of this invention can be carried out either batchwise or continuously while maintaining the reaction mass at or above 0°C. but below the melting points of the thiohydroximate precursor (compound of formula II) and the thiohydroximate carbamate end product (compound of formula I). It is preferred to operate at or above 25°C. but below the temperature at which the reaction mass becomes tacky.

The process can be carried out at reduced or elevated pressures, but atmospheric pressure is preferred for economic reasons.

The preferred molar ratio of methyl isocyanate to the hydroximate is 0.95:1 to 1.05:1 although 0.98:1 to 1.02:1 is the most preferred ratio. More than the stoichiometric amount of isocyanate can be used, but this results in increased impurities and a waste of the isocyanate.

The methyl isocyanate can be added to the reaction mass over a period of time from 1 to 12 hours. The time will depend mainly on rate of removal of heat of reaction and rate of diffusion of methyl isocyanate into the hydroximate particles. The more preferred isocyanate addition time ranges from 1 to 5 hours followed by a 1 to 2 hour hold period which allows any residual, unreacted isocyanate to react.

The rates of heat removal and isocyanate addition are ordinarily balanced so as to maintain the reaction mass at the desired temperature and degree of "moistness". It is most preferred to balance these rates so that the reaction mass is maintained in a moist powdery state throughout the isocyanate addition.

Use of a catalyst is optional in some cases. For example, a catalyst has been found necessary for producing the compound where R is



but has not been found essential when R is any other group. However, use of a catalyst is preferred in all cases. Suitable catalysts include triethylamine, triethylenediamine, other such tertiary amines and alkali metal hydroxides such as sodium and potassium hydroxide. The preferred amount of catalyst is .001 to .01 moles of catalyst per mole of hydroximate.

If desired, a heel of finished hydroximate carbamate from previous production and/or solid, inert, particulate diluents can be mixed with the hydroximate particles before or during the reaction to reduce the tackiness of the reaction mass. Any amount of heel can be used, but as a practical matter it will not exceed about 95% by weight of the reaction mass at the start of isocyanate addition. The

amount of inert diluent likewise will ordinarily not exceed 95% by weight of the reaction mass. Where both a heel and an inert diluent are used, the hydroximate reactant ordinarily should comprise at least 5% by weight of the reaction mass at the start of the isocyanate addition, merely to avoid undue dilution of the reactant.

Inert diluents which can be used are those which are ordinarily used in solid, particulate agricultural formulations so that the product can be used in agriculture without further substantial processing. Examples of inerts which can be used are ammonium sulfate, sodium sulfate, urea, potassium chloride, synthetic precipitated hydrated silicon dioxide, diatomaceous earths, and clays such as those listed in Wiedhaus and Brann, *Handbook of Insecticide Dust Diluents and Carriers*, Dorland Books (1955). Some of these have a plant physiological effect, but they are considered inert for the purpose of this invention in that they do not enter into the reaction. The concentration of inert diluent in the reaction mass should not exceed the concentration desired in the final product. If desired, inerts can be added after the reaction is complete. Dispersants and anti-caking agents can also be included in the reaction mass. Suitable dispersants are listed in McCutcheon, *Detergents and Emulsifiers Annual*, 1970. Colloidal silica is a particularly suitable anti-caking agent.

The reaction vessel will desirably be a mixing machine capable of producing a homogeneous reaction mass. Illustrative of such mixers that may be used are — "Change-Can" mixer, "Horseshoe" mixer with contrarotating paddles, "Kneader" mix or "Sigmablade" mixer, mix-muller, pug mill, ribbon blender, ball mill, "V" blender, and double-cone blender. The mixer that is preferred is the mix-muller. In the mix-muller, heavy, solid metal wheels roll around the bottom periphery of a circular pan. Plows continually move the solid particles into the path of the heavy wheels. Particle size reduction takes place during mixing due to the action of the wheels on particles between the wheels and bottom and sides of the vessel. Some of the other types of mixers mentioned above also produce particle size reduction during mixing.

Particle size of the thiohydroximate reactant is not critical, but for best results the bulk of the particles should be below 5 mesh (as defined by the U.S. Sieve Series) before or during the reaction. Larger particles can be used with reaction vessels which produce particle size reduction during mixing. It is preferred that the bulk of the starting material be in the form of particles which will pass a 20 mesh sieve.

As indicated above, the rates of isocyanate addition and heat removal must be balanced so as to avoid formation of a continuous

liquid phase and preferably so as to maintain the reaction mass in the form of a damp powder. In order to permit an acceptable rate of isocyanate addition, the reaction vessel will desirably be fitted with a water cooled jacket, or other means may be used to accelerate heat removal.

In addition to performing the reaction as described in detail above, the alternative process for making the compound of formula I where R and R₁ are both methyl (i.e., S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate) can also be carried out either batchwise or continuously under conditions such that, for at least a terminal portion of the reaction, the reaction mass is maintained as a continuous liquid phase. Accordingly, at the completion of the reaction the temperature of the reaction mass will preferably be between 70° and 120°C. It is preferred to operate so that the final reaction mass temperature is between 70° and 100°C. and an optimum yield and quality may be achieved by balancing the rates of reactant addition and heat removal so that final reaction mass is between 75° and 85°C.

Higher temperatures will increase the amounts of side reactions and production of undesirable by-products and will also increase the decomposition of the reaction product as well as decomposition of the precursor reactant. Lower temperatures will result in incomplete reaction or in the reaction mass becoming tacky and therefore difficult to handle.

As mentioned above, the reaction mass should be maintained as a continuous liquid phase for at least a terminal portion of the reaction. It is preferred that such continuous liquid phase be maintained for at least the terminal 5% of the reaction, i.e., for at least that portion of the reaction where 5% (by weight) of the reactants remain unreacted. It is more preferred that such continuous liquid phase be maintained for at least the terminal 25% of the reaction. It is most preferred that methyl isocyanate is contacted with solid S-methyl N-hydroxythioacetimidate and that the temperature of the reaction mass be permitted to rise autogeneously at the beginning of the reaction until the reaction mass becomes a continuous liquid phase, and that such continuous liquid phase be maintained for the remainder of the reaction. Performing the reaction thus, permits a very rapid and complete reaction while keeping side reactions and decomposition to a minimum.

The advantages of producing S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate by the alternative process of the present invention rather than by the wholly solid-state process described above include higher yields of the finished product and being able to use lighter, less expensive equipment. It will be apparent that as more of the reaction is run while maintaining the reaction mass as a continuous

liquid phase, the latter advantage becomes even more significant.

By reference to the graph shown in Figure I of the accompanying drawings, which is the solid-liquid phase diagram for binary mixtures of purified S-methyl N-hydroxythioacetimidate and purified S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate, it can be seen that where both the precursor and the product thioacetimidate are purified, the eutectic melting point is approximately 47°C, and the eutectic composition is approximately 67% (by weight) of S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate. Thus, in the preferred embodiments, the reaction mass should be maintained at a temperature sufficiently above the eutectic melting point to maintain the reaction mass as a continuous liquid phase. The temperature necessary to accomplish this will vary as indicated by the phase diagram as the reaction progresses from left to right in the graph. The presence of impurities will lower the eutectic melting point, and adjustments in operating conditions can be made accordingly.

In performing the reaction batchwise, two basic embodiments are possible. First, the methyl isocyanate can be added over a period of time to the precursor thioacetimidate. The reaction proceeds extremely rapidly, and for all practical purposes the quantity of isocyanate in the reaction mass will be minor, and the reaction mass will consist essentially of precursor thioacetimidate and product thioacetimidate. The solid-liquid phase diagram for such a binary mixture (assuming purified S-methyl N-hydroxythioacetimidate and purified S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate) is shown in Figure 1.

Second, the precursor thioacetimidate can be added over a period of time to the methyl isocyanate. Similarly, the reaction proceeds extremely rapidly, and for all practical purposes the quantity of precursor thioacetimidate in the reaction mass is minor, and the reaction mass will consist essentially of methyl isocyanate and product thioacetimidate. A partial solid-liquid phase diagram for such a binary mixture (assuming purified precursor and product thioacetimidate) is shown in Figure 2 of the accompanying drawings.

In both of these embodiments the reactants can initially be at room temperature or they can be preheated. In preheating the reactants, care must be taken to prevent temperatures so high that significant decomposition will occur before the reaction commences or during the early stages of the reaction. It must be remembered that the reaction is exothermic and preheating the reactants is optional. As mentioned above, a suitable alternative is to permit the temperature of the reaction mass to rise autogeneously until a continuous liquid phase occurs and/or until the desired final

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temperature is achieved. Thus, the methyl isocyanate can initially be either liquid or gaseous. The S-methyl N-hydroxythioacetimidate will in this case initially be solid.

As with the solid-state reaction described above, if desired, a heel of finished S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate from previous production can be mixed with the precursor thioacetimidate before or during the reaction. Any amount of heel can be used but as a practical matter, this will not exceed 95% by weight of the total amount of said thioacetimidates at the start of the reaction addition. As can be seen from the phase diagram shown in Figure 1, depending upon the amount of heel added to the S-methyl N-hydroxythioacetimidate, this mixture can be preheated sufficiently to create a continuous liquid phase at temperatures as low as approximately 47°C.; and a continuous liquid phase will occur at even lower temperatures in the presence of impurities. Thus, under certain conditions it might be desirable to run the reaction with the reaction mass maintained as a continuous liquid phase for the entire period of the reaction.

In addition, inert solid diluents and/or anti-caking agents can be mixed with the precursor thioacetimidate before or during the reaction. The amount of diluent will likewise ordinarily not exceed 95% by weight of the total weight of said thioacetimidates. And the amount of anti-caking agent will generally not exceed about 1/2% by weight of the reaction mass. Where more than one of these three materials are used, their combined amount should not ordinarily exceed 95% by weight of the reaction mass, in order to avoid undue dilution of the reactants. The molar ratio of isocyanate to thioacetimidate reactant will desirably be from 0.95:1 to 1.05:1.

Inert diluents, dispersants, and anti-caking agents which can be used are those described above in connection with the solid-state process of the present invention.

Addition of the reactants may occur over a period of time from five minutes to as much as two hours. The length of time will depend primarily on the rate of removal of heat produced by the reaction and the degree of agitation and intermixing of the reactants. It is preferred that addition of the reactants is accomplished within a period of 30 minutes followed by a period of at least 5 minutes to allow the reaction to go to completion.

After the reaction mass becomes a continuous liquid phase, either by preheating the reactants, by permitting the temperature of the reaction mass to rise autogeneously, or by a combination of these, the rates of heat removal and reactant addition will generally be balanced so as to maintain the reaction mass at the desired temperature, i.e., the temperature of the reaction mass should be high enough to prevent tackiness but low enough

to avoid side reactions and decomposition. A final temperature of from 75° to 85°C. will result in optimum yield of the highest quality product.

Use of a catalyst is optional. Suitable types and amounts of catalysts include those mentioned above in connection with the solid-state process of the present invention.

The reaction can be conducted in any vessel that will provide uniform mixing of reagents. Examples of such vessels include an agitated kettle or autoclave, a ribbon blender, or a sigma arm mixer. Because the reaction mass is maintained mostly or completely in a liquid condition, the mixing equipment can be lighter than that required for a solid phase reaction and power requirements will also be substantially less.

One of the most surprising and most attractive features of the present invention, which is also one of the major advantages of the present process, is that the molten, liquid phase reaction product may be allowed to cool to below 79°C. directly in the mixing apparatus, e.g., in the sigma arm mixer, to give a free-flowing crystalline powder possessing good handling properties without the formation of any highly viscous, sticky masses which would normally be expected in the direct cooling of a molten organic reaction product. This eliminates the necessity for a separate cooling apparatus, and thereby reduces both the initial investment required as well as operating expenses. Of course, if desired, the reaction mass can be removed from the reaction vessel in the liquid state and solidified into a usable form by conventional procedures, for example, flaking or spraying into a cool agitated bed of solid particles so as to cool the crystalline solids to 35°-40°C.

Cooling of the reaction product may also be accomplished by addition of the molten product directly to a methanol/water mixture thus producing a liquid formulation, as described in U.S. Patent No. 3862316. Thus, the reaction product may be cooled at the same time it is being dissolved in the above-mentioned solvent thus eliminating separate cooling and dissolution steps. This liquid formulation is especially useful and easy to use as is discussed in detail in the above-mentioned U.S. patent.

The S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate can be added to the methanol/water mixture in an amount sufficient to make the final concentration of the thioacetimidate from 10% by weight to 30% by weight thioacetimidate. The methanol/water mixture can contain from 20% to 95% methanol.

The following examples illustrate the solid-state process (a) of the present invention.

EXAMPLE 1

Five hundred grams (4.68 g.-moles) of

technical S-methyl thioacetohydroximate, containing 1.6% by weight potassium chloride, were charged to a 12-inch diameter mix-muller fitted with a reflux condenser. The agitator was started and 3.4 mls. (2.48 grams) (0.024 g.-moles) of triethylamine were added; this was followed by the uniform addition of 276.6 grams (4.85 g.-moles) of technical methyl isocyanate over two hours during which period the temperature of the solids was kept below 40°C. by external cooling with water. During the addition of the isocyanate the reaction contents had the appearance of damp particulate solids. Agitation of the solids was maintained for two more hours while the temperature decreased to 31°C. There were recovered 768 grams (4.55 g.-moles) of granular technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate. A liquid chromatography assay of the product indicated it was 96.2% pure.

EXAMPLE 2

Five hundred and three grams (3.0 g.-moles) of technical S-methyl 1 - (dimethylcarbamoyl) thioformhydroximate were charged to a 12-inch diameter mix-muller fitted with a reflux condenser. The agitator was started and 2.2 ml. (1.6 grams) (0.0158 g.-moles) of trimethylamine were charged. This was followed by the uniform addition of 184.6 grams (3.24 g.-moles) of methyl isocyanate over a two-hour period during which the temperature of the solids was kept between 26°C. and 38°C. by external cooling with water. Agitation of the solids was maintained for an additional two-hour period. There were recovered 680 grams (2.97 g.-moles) of technical S-methyl 1 - (dimethylcarbamoyl) - N - [(methylcarbamoyl)oxy]thioformimidate, 95.8% pure by liquid chromatography assay.

EXAMPLE 3

105 Pounds (454 g.-moles) of technical S-methyl thioacetohydroximate were ground in a MikroPulverizer so that it all passed through a 150 U.S. Mesh screen. The finely divided material was charged to a five cubic feet stainless steel double ribbon blender fitted with water cooled jacket, a water cooled reflux condenser, and a solids temperature indicator. The agitator was started and 236 grams (2.33 g.-moles) of triethylamine were charged to the agitated solids over 15 minutes. 58 1/2 pounds (466 g.-moles) of technical methyl isocyanate were added uniformly over three hours while maintaining the temperature of the agitated solids below 40°C. by adjusting the flow and temperature of the water circulated through the jacket of the blender. The isocyanate charge was introduced into the blender through four equally spaced nozzles installed under the blender lid along the central axial position and aimed at the bed of agitated solids. Agitation of the solids

was maintained for two hours after the isocyanate charge is finished. During this period, the temperature of the solids was decreased to 28°C. 161 Pounds (451 g.-moles) of high quality technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate were recovered.

EXAMPLE 4

42 Pounds (181 g.-moles) of technical S-methyl thioacetohydroximate were ground in a MikroPulverizer so that it all passed through a 150 U.S. Mesh screen. The finely divided material was charged to a tightly sealed two cubic feet nominal capacity stainless steel double ribbon vacuum drier fitted with a vacuum take-off, a jacket for cooling or heating, and a solids temperature indicator. The agitator was started and the internal vessel pressure reduced to 25 mm. Hg. abs. Triethylamine (approximately 0.28 g.-moles) was admitted into the vessel until the pressure increased to 100 mm. Hg. abs. 23 2/3 Pounds (185 g.-moles) of methyl isocyanate were admitted into the vessel at such a rate that the solids temperature did not exceed 50°C. and the vessel internal pressure did not exceed 600 mm. Hg. abs. After all the methyl isocyanate was charged, the resulting solids were agitated for two more hours in the tightly sealed vessel, then air admitted into the vessel until the pressure was equal to atmospheric. High quality technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate was discharged from the vessel.

EXAMPLE 5

400 Grams (2.47 g.-moles) of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate produced as per Example 1 were charged to a 12-inch diameter mix-muller fitted with a reflux condenser along with 500 grams (4.68 g.-moles) of technical S-methyl thioacetohydroximate containing 1.6% by weight potassium chloride. Triethylamine catalyst and methyl isocyanate were added in the amount and manner prescribed by Example 1. (Agitation of the solids for two more hours was maintained after completion of the isocyanate addition). 1165 Grams (7.19 g.-moles) of granular technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate of high purity were recovered.

The following examples illustrate the process (b) for producing S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate under conditions such that the reaction mass is a continuous liquid phase for at least a terminal portion of the reaction.

EXAMPLE 6

105.2 Grams of technical S-methyl N-hydroxythioacetimidate were charged to a 500-milliliter round bottom flask fitted with an addition funnel, thermometer, reflux condenser and agitator. The solids were heated

to 45°C. with mixing and 1.1 milliliters of triethylamine were added. This was followed by the uniform addition of 57.1 grams of methyl isocyanate over a period of approximately 15 minutes during which the temperature rose autogeneously to 84°C., and was maintained at 80° to 85°C. with a cold water bath. 158.7 Grams of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate were recovered, 98.1% pure.

EXAMPLE 7

585.0 Grams of technical S-methyl N-hydroxythioacetimidate and 300.0 grams of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate (98.2% pure) were charged to a 5.0 liter sigma arm mixer fitted with a reflux condenser, addition funnel, and temperature readout. The bed was mixed for 10 minutes, heated to 40°C., and 6.0 milliliters of triethylamine were added. This was followed by the uniform addition of 327.5 grams of methyl isocyanate over 10 minutes during which time the temperature rose to and was maintained at 80 to 85°C. by circulating 60°C water through the mixer jacket. Following the addition, the mass was held at this temperature for 10 minutes. 1,183.0 grams of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate was recovered, 97.8% pure.

EXAMPLE 8

57.1 Grams of methyl isocyanate were charged to a 250 milliliter round bottom flask fitted with a thermometer, reflux condenser, agitator, and solids feeder. 105.2 Grams of solid S-methyl N-hydroxythioacetimidate was fed to the isocyanate over a period of 15 minutes during which time the temperature rose autogeneously from 23°C. to 85°C. The temperature was maintained at approximately 80° to 85°C. with an ice bath. 159.4 Grams of S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate were recovered, 97.4% pure.

EXAMPLE 9

The molten S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate prepared by the procedure in Example 7 was cooled to approximately 75°C., and maintained at this temperature for about 15 minutes to allow crystals to form. Following this hold period, the solids are further cooled to about 35 to 40°C., and 1.0% by weight of anti-caking agent is added and mixed with the product for 2 to 3 minutes. The resulting S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate product is granular and free-flowing.

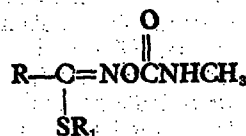
EXAMPLE 10

The molten S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate produced as in Example 7 is discharged as a liquid into a

mixture of methanol and water at a rate such that the temperature of the resulting solution does not exceed 50°C. The resulting solution is convenient and easy to use.

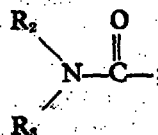
WHAT WE CLAIM IS:—

1. A process for the preparation of S-alkyl thiohydroximate carbamates of the formula:



wherein

R is methyl, ethyl, or



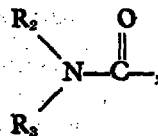
R₁ is methyl, ethyl, *n*-propyl, or isopropyl; R₂ is hydrogen, methyl, ethyl, *n*-propyl, or isopropyl; and

R₃ is hydrogen or methyl, provided that when R₂ is ethyl, *n*-propyl or isopropyl, R₃ is hydrogen;

in which methyl isocyanate is reacted with an S-alkyl thiohydroximate of the formula:



wherein R and R₁ are as defined above, the reaction being carried out (a) at least in part, by adding the methyl isocyanate, in gaseous or liquid form, to an agitated bed of solid particles of the S-alkyl thiohydroximate in the absence of a continuous liquid phase, a catalyst being present when R represents the group



while removing the heat of reaction, the rates of isocyanate addition and heat removal being balanced so as to maintain the temperature of the reaction mass at or above 0°C. but below the melting points of the thiohydroximate starting material and the thiohydroximate carbamate product and/or (b) by contacting the reactants, in the case where R and R₁ are both methyl, in the absence of a solvent under conditions such that for at least a terminal portion of the reaction, the reaction

to 45°C. with mixing and 1.1 milliliters of triethylamine were added. This was followed by the uniform addition of 57.1 grams of methyl isocyanate over a period of approximately 15 minutes during which the temperature rose autogeneously to 84°C., and was maintained at 80° to 85°C. with a cold water bath. 158.7 Grams of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate were recovered, 98.1% pure.

EXAMPLE 7

585.0 Grams of technical S-methyl N-hydroxythioacetimidate and 300.0 grams of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate (98.2% pure) were charged to a 5.0 liter sigma arm mixer fitted with a reflux condenser, addition funnel, and temperature readout. The bed was mixed for 10 minutes, heated to 40°C., and 6.0 milliliters of triethylamine were added. This was followed by the uniform addition of 327.5 grams of methyl isocyanate over 10 minutes during which time the temperature rose to and was maintained at 80 to 85°C. by circulating 60°C water through the mixer jacket. Following the addition, the mass was held at this temperature for 10 minutes. 1,183.0 grams of technical S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate was recovered, 97.8% pure.

EXAMPLE 8

57.1 Grams of methyl isocyanate were charged to a 250 milliliter round bottom flask fitted with a thermometer, reflux condenser, agitator, and solids feeder. 105.2 Grams of solid S-methyl N-hydroxythioacetimidate was fed to the isocyanate over a period of 15 minutes during which time the temperature rose autogeneously from 23°C. to 85°C. The temperature was maintained at approximately 80° to 85°C. with an ice bath. 159.4 Grams of S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate were recovered, 97.4% pure.

EXAMPLE 9

The molten S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate prepared by the procedure in Example 7 was cooled to approximately 75°C., and maintained at this temperature for about 15 minutes to allow crystals to form. Following this hold period, the solids are further cooled to about 35 to 40°C., and 1.0% by weight of anti-caking agent is added and mixed with the product for 2 to 3 minutes. The resulting S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate product is granular and free-flowing.

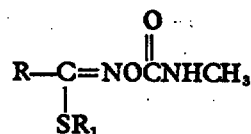
EXAMPLE 10

The molten S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate produced as in Example 7 is discharged as a liquid into a

mixture of methanol and water at a rate such that the temperature of the resulting solution does not exceed 50°C. The resulting solution is convenient and easy to use.

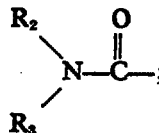
WHAT WE CLAIM IS:—

1. A process for the preparation of S-alkyl thiohydroximate carbamates of the formula:



wherein

R is methyl, ethyl, or

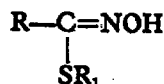


R₁ is methyl, ethyl, n-propyl, or isopropyl;

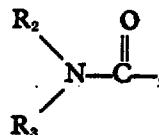
R₂ is hydrogen, methyl, ethyl, n-propyl, or isopropyl; and

R₃ is hydrogen or methyl, provided that when R₂ is ethyl, n-propyl or isopropyl, R₃ is hydrogen;

in which methyl isocyanate is reacted with an S-alkyl thiohydroximate of the formula:



wherein R and R₁ are as defined above, the reaction being carried out (a) at least in part, by adding the methyl isocyanate, in gaseous or liquid form, to an agitated bed of solid particles of the S-alkyl thiohydroximate in the absence of a continuous liquid phase, a catalyst being present when R represents the group



while removing the heat of reaction, the rates of isocyanate addition and heat removal being balanced so as to maintain the temperature of the reaction mass at or above 0°C. but below the melting points of the thiohydroximate starting material and the thiohydroximate carbamate product and/or (b) by contacting the reactants, in the case where R and R₁ are both methyl, in the absence of a solvent under conditions such that for at least a terminal portion of the reaction, the reaction



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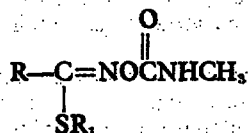
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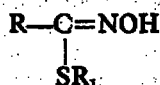
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mass is maintained as a continuous liquid phase.

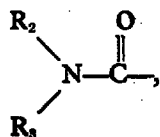
2. A process for the preparation of S-alkyl thiohydroximate carbamates of the formula:



wherein R and R₁ are as defined in claim 1 in which methyl isocyanate is reacted with an S-alkyl thiohydroximate of the formula



- 10 wherein R and R₁ are as defined in claim 1, the reaction being carried out at least in part, by adding the methyl isocyanate, in gaseous or liquid form, to an agitated bed of solid particles of the S-alkyl thiohydroximate in the absence of a continuous liquid phase, a catalyst being present when R represents the group



- 20 while removing the heat of reaction, the rates of isocyanate addition and heat removal being balanced so as to maintain the temperature of the reaction mass at or above 0°C. but below the melting points of the thiohydroximate starting material and the thiohydroximate carbamate product.

- 25 3. A process as claimed in claim 1(a) or claim 2 wherein the rate of isocyanate addition and heat removal are balanced so as to maintain the temperature of the reaction mass at or above 25°C but below the temperature at which the reaction mass becomes tacky.

- 30 4. A process as claimed in any of the preceding claims wherein the rates of isocyanate addition and heat removal are balanced such that the reaction mass is maintained in a moist powdery state throughout the period of isocyanate addition.

- 35 5. A process as claimed in any of the preceding claims wherein at least one solid particulate inert diluent or a heel or the thiohydroximate carbamate is mixed with the thiohydroximate reactant particles before or during the reaction.

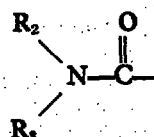
- 40 6. A process as claimed in any of claims 1 to 4 wherein at least one solid particulate inert diluent and a heel of the thiohydroximate carbamate are mixed with the thiohydroximate reactant before or during the reaction.

7. A process as claimed in any of the preceding claims wherein the mole ratio of isocyanate to thiohydroximate is in the range of 0.95:1 to 1.05:1.

8. A process as claimed in claim 7 wherein the mole ratio of isocyanate to thiohydroximate is in the range of 0.98:1 to 1.02:1.

9. A process as claimed in any of the preceding claims wherein a catalytic amount of a tertiary amine or alkali metal hydroxide is present in the reaction mass.

10. A process as claimed in claim 9 wherein R is



and R₁, R₂, and R₃ are methyl.

11. A process as claimed in claim 9 wherein R and R₁ are both methyl.

12. A process as claimed in claim 1(a) or claim 2 substantially as hereinbefore described.

13. A process as claimed in claim 1(a) or claim 2 substantially as hereinbefore described with reference to Examples 1—5.

14. A process for the preparation of S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate which comprises reacting methyl isocyanate with S-methyl N-hydroxythioacetimidate in the absence of solvent, and contacting the reactants under conditions such that for at least a terminal portion of the reaction the reaction mass is maintained as a continuous liquid phase.

15. A process as claimed in claim 1(b) or claim 14 wherein the reaction mass is maintained as a continuous liquid phase for at least the terminal 5% (as herein defined) of the reaction.

16. A process as claimed in claim 1(b) or claim 15 wherein the reaction mass is maintained as a continuous liquid phase for at least the terminal 25% (as herein defined) of the reaction.

17. A process as claimed in claim 1(b) and any of claims 14 to 16 wherein the rates of reactant addition and heat removal are balanced such that at the completion of the reaction the temperature of the reaction mass is between 75° and 85°C.

18. A process as claimed in claim 1(b) and any of claims 14—17 wherein the methyl isocyanate is contacted with solid S-methyl N-hydroxythioacetimidate, and further wherein the temperature of the reaction mass is permitted to rise autogeneously at the beginning of the reaction until said reaction mass becomes a continuous liquid phase, and the reaction mass is maintained as a continuous liquid phase for the remainder of the reaction.

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19. A process as claimed in claim 1(b) and any of claims 14—18 wherein gaseous methyl isocyanate is contacted with said solid S-methyl N-hydroxythioacetimidate.
- 5 20. A process as claimed in claim 1(b) and claims 14—19 wherein an inert solid diluent and/or anti-caking agent and/or S-methyl N - [(methylcarbamoyl)oxy]thioacetimidate heel is mixed with at least one of the reactants before or during the reaction.
- 10 21. A process as claimed in claim 1(b) and claims 14—20 wherein the molar ratio of isocyanate to thioacetimidate reactant is from 0.95:1 to 1.05:1.
- 15 22. A process as claimed in claim 1(b) and claims 14—21 wherein a catalytic amount of a tertiary amine or alkali metal hydroxide is present in the reaction mass.
- 20 23. A process as claimed in claim 1(b) and claims 14—22 further comprising cooling the

reaction product sufficiently to convert it from the molten state to a crystalline solid state, and thereafter further cooling the crystalline solids to 35° to 40°C.

24. A process as claimed in claim 1(b) or claim 14 substantially as hereinbefore described.

25. A process as claimed in claim 1(b) or claim 14 substantially as hereinbefore described with reference to Examples 6 to 10.

26. S-alkyl thiohydroximate carbonates whenever prepared by a process as claimed in any of claims 1 to 25.

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