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(71) Applicant: **ALBEMARLE CORPORATION** [US/US];
4350 Congress Street, Suite 700, Charlotte, NC 28209-4953
(US).

(72) Inventors: **WU, Tse-Chong**; 17613 Eaglewood Drive, Ba-
ton Rouge, LA 70810 (US). **VARNADO, Daniel**; 33500
Marion Drive, Denham Springs, LA 70706 (US).

(74) Agent: **KLECKLEY, Troy** et al.; Albemarle Corporation,
4350 Congress Street, Suite 700, Charlotte, NC 28209-4953
(US).

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(54) Title: SYNTHESIS AND PREPARATION OF 2, 3-DIBROMO-2-PROPEN-1-OL

(57) Abstract: The disclosure describes methods for preparing 2,3-dibromo-2-propen-1-ol, or dibromoallyl alcohol, and isomerically enriched compositions of the same. The process can include reacting propargyl alcohol with elemental bromine to produce the di-bromo product. High yields of the dibromoallyl alcohol can be achieved, with E-isomer content of greater than 95%.



WO 2019/067883 A1

SYNTHESIS AND PREPARATION OF 2,3-DIBROMO-2-PROPEN-1-OL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application, filed September 28, 2018, claims the benefit of U.S. Provisional Patent Application Ser. No. 62/564,532, filed September 28, 2017, entitled “BROMINATED FLAME RETARDANT AND ITS APPLICATION IN POLYURETHANE FOAMS,” the entire contents and substance of which are hereby incorporated by reference as if fully set forth below.

TECHNICAL FIELD

[0002] The various embodiments of the disclosure relate generally to a brominated short-chain alcohol useful as a flame retardant in various materials, including in flexible and rigid polyurethane foams.

BACKGROUND

[0003] Fire resistance is an important property for many materials, including polyurethane foams. Various compounds or mixtures thereof have been used effectively to meet applicable fire safety standards. Tris(1-chloro-2-propyl) phosphate (TCPP) is a flame retardant widely used in polyurethane foams. However, TCPP is a non-reactive compound in polyurethane foam formation and can thus leach or migrate from the foams. This results in health and environmental concern.

[0004] A brominated isocyanate-reactive compound that has been disclosed as a flame retardant is 2,3-dibromobutene-1,4-diol (e.g., U.S. Patent No. 4,002,580). However, 2,3-dibromobutene-1,4-diol (DBBD) is a solid with a high melting point and requires additional steps to pre-dissolve for it to be useful in polyurethane foam applications.

[0005] Two recently filed and co-owned applications (PCT/US2018/039578 and PCT/US2018/039562) disclose flame retardant compositions of polyurethane foams, which can be prepared using a brominated short chain alcohol, dibromoallyl alcohol (DBAA.) The brominated short chain alcohol can be a liquid at processing conditions and has low viscosity to allow ease of processing (mixing and pumping). In addition to its effectiveness as flame retardants, it provides compounds that are compatible with polyurethane foam manufacturing processes and do not migrate out of the polyurethane foam over time, lessening the health and environmental impacts.

BRIEF SUMMARY

[0006] The various embodiments of the disclosure relate generally to processes and method for preparing 2,3-dibromo-2-propen-1-ol.

[0007] An embodiment of the disclosure can be a process for preparing 2,3-dibromo-2-propen-1-ol, which process includes contacting 2-propyn-1-ol and elemental bromine at a temperature in the range of about -5°C about 15°C . The process can include dissolving the 2-propyn-1-ol in a protic solvent prior to contacting with elemental bromine. The protic solvent can be an aqueous solution, water, or a solution of an alkali metal salt and water. The 2-propyn-1-ol can also be contacted with the elemental bromine as a neat solution.

[0008] Some embodiments can also include subsequently treating the reaction with a basic aqueous solution. The basic aqueous solution can include a hydroxide, carbonate or bicarbonate solution.

[0009] Some embodiments can include conducting the reaction at an initial temperature of less than 10°C .

[0010] Other embodiments can include the process above, wherein the 2,3-dibromo-2-propen-1-ol product has an *E* isomer content of at least 95% weight.

[0011] Another embodiment of the disclosure can be a process for preparing 2,3-dibromo-2-propen-1-ol which includes the steps of preparing a 2-propyn-1-ol solution, contacting the 2-propyn-1-ol solution with elemental bromine, and quenching the reaction with a base.

[0012] In some embodiments, the 2-propyn-1-ol solution can include no solvent; in other words, a neat solution of 2-propyn-1-ol. In some embodiments, the 2-propyn-1-ol solution can include a protic solvent. The protic solvent can include a C_1 to C_4 alcohol. In some embodiments, the protic solvent can include an aqueous solvent. The aqueous solvent can include water, or can include water and an alkali bromide salt.

[0013] In some embodiments, the reaction can be conducted at a temperature below 40°C . In some embodiments, the reaction can be conducted at an initial temperature below 15°C .

[0014] Some embodiments of the disclosure can include quenching the reaction with a base. The base can be a basic aqueous solution, and can include a hydroxide, carbonate or bicarbonate solution, or a combination thereof.

[0015] Another embodiment of the disclosure can include a process for preparing the 2,3-dibromo-2-propen-1-ol, wherein the 2,3-dibromo-2-propen-1-ol has an *E* isomer content of at least 95%, and wherein the process comprises reacting propargyl alcohol with elemental bromine in the absence of graphite. The 2-propyn-1-ol can be a neat solution or can be dissolved in a protic solvent, such as an aqueous solvent.

[0016] Another embodiment of the disclosure can be a composition comprising 2,3-dibromo-2-propen-1-ol, having an *E* isomer content of at least 95%.

DETAILED DESCRIPTION

[0017] Although preferred embodiments of the disclosure are explained in detail, it is to be understood that other embodiments are contemplated. Accordingly, it is not intended that the disclosure is limited in its scope to the details of construction and arrangement of components set forth in the following description or illustrated in the drawings. The disclosure is capable of other embodiments and of being practiced or carried out in various ways. Also, in describing the preferred embodiments, specific terminology will be resorted to for the sake of clarity.

[0018] It must also be noted that, as used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless the context clearly dictates otherwise.

[0019] Also, in describing the preferred embodiments, terminology will be resorted to for the sake of clarity. It is intended that each term contemplates its broadest meaning as understood by those skilled in the art and includes all technical equivalents which operate in a similar manner to accomplish a similar purpose.

[0020] Ranges can be expressed herein as from “about” or “approximately” one particular value and/or to “about” or “approximately” another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value.

[0021] By “composing” or “comprising” or “including” is meant that at least the named compound, element, particle, or method step is present in the composition or article or method, but does not exclude the presence of other compounds, materials, particles, method steps, even if the other such compounds, material, particles, method steps have the same function as what is named.

[0022] It is also to be understood that the mention of one or more method steps does not preclude the presence of additional method steps or intervening method steps between those steps expressly identified. Similarly, it is also to be understood that the mention of one or more components in a device or system does not preclude the presence of additional components or intervening components between those components expressly identified.

[0023] The disclosure provides a process for production of 2,3-dibromo-2-propen-1-ol, or dibromoallyl alcohol (DBAA). DBAA can be a flame retardant, including but not limited to a reactive flame retardant used in polyurethane foams. These foams can be formed from formulations comprising DBAA, at least one polyol, at least one blowing agent, at least one catalyst, and at least one surfactant, which formulations are contacted with a polyisocyanate.

[0024] The isocyanate-reactive brominated flame retardant DBAA, chemically named as 2,3-dibromo-2-propen-1-ol, has a CAS[®] registry number 7228-11-7 (Chemical Abstracts Service). In the past, DBAA has been used as an intermediate to make phosphorus compounds (see U.S. Pat. No. 3,950,457). DBAA can be used in forming both flexible polyurethane foams and rigid polyurethane foams. DBAA can be used as a reactive component that becomes part of a polyurethane foam. This provides the advantage that DBAA does not migrate out of the foam. Another advantage can be that DBAA has a high bromine content (74 wt%), and can be used more generally as a possible flame retardant in other applications.

[0025] While DBAA is a known molecule, it is not commercially available. Synthesis of DBAA from propargyl alcohol (2-propyn-1-ol) and elemental bromine (Br₂) at room temperature in carbon tetrachloride has been reported in U.S. Pat. No. 3,780,144; it is also reported therein that DBAA can be prepared from 1,2,3-tribromopropene and sodium carbonate, although synthetic details were not extensive.

[0026] Another synthesis of DBAA from propargyl alcohol and elemental bromine at 5-8 °C in dichloromethane was reported in U.S. Pat. No. 3,932,181.

[0027] Notably, both references rely on halogenated solvents to achieve reaction. Both methylene chloride and carbon tetrachloride carry environmental, health and exposure risks that are preferably avoided in chemical synthesis, and especially in industrial scale preparations of chemical compounds. Carbon tetrachloride in particular is a recognized toxin and ozone-depleting compound. An improved process that provides DBAA is thus desirable in order to make DBAA commercially available as a common flame retardant material. Moreover, a reaction that can eliminate the need for an organic solvent can be both more environmentally friendly, i.e. “greener”, and economically preferable on a commercial scale since the additional solvent adds costs and requires additional capital expenditure to separate and recollect the organic solvent. The processes described below can achieve these desired goals.

[0028] The disclosure includes a process for preparing 2,3-dibromo-2-propen-1-ol, which process comprises contacting 2-propyn-1-ol and elemental bromine at a temperature in the range of about -5°C about 15°C. The compound 2-propyn-1-ol can similarly be referred to as, and is interchangeably described by the terms of, propargyl alcohol, 2-propynol, propynyl alcohol, or propynol.

[0029] The disclosure can similarly include a process for preparing 2,3-dibromo-2-propen-1-ol, comprising the steps of preparing a propargyl alcohol solution, contacting the propargyl

alcohol solution with elemental bromine, and quenching the reaction with a base to yield DBAA.

[0030] The process includes an initial solution of 2-propyn-1-ol, also interchangeably described as propargyl alcohol. The solution can be a neat solution of the propargyl alcohol. The solution can also be a protic solution of the propargyl alcohol in a protic solvent. Protic solvent is understood by one of ordinary skill as having a labile proton. Protic solvent can include alcohols or water. The protic solvent can be a C₁ to C₄ alcohol solution. The protic solvent can be an aqueous solution. The aqueous solution can comprise water, or can comprise an aqueous salt solution. Preferably, the solution can comprise water or an aqueous salt solution.

[0031] In cases where the propargyl alcohol solution comprises an aqueous salt solution, the salt can be any non-reactive salt that depresses the freezing point of water. The aqueous salt solution can be preferably an alkali halide salt, preferably an alkali bromide salt. The salt solution can be between about 5% to 30% by weight of salt in water, more preferably between about 10% and about 25% by weight of salt in water.

[0032] In the disclosure, the brominating agent can be elemental bromine, i.e. Br₂. Elemental bromine is known by those of skill in the art, and is a liquid under reaction conditions. The solution of propargyl alcohol, either as a protic solution, aqueous solution, or neat, can be contacted with the elemental bromine to effect the reaction.

[0033] An aspect of the disclosure also includes controlling the reaction temperature of the bromination. The reaction can be controlled both at its initial reaction temperature, and during the course of the bromination reaction. The reaction is an exothermic reaction and can have an initial low reaction mass. Thus, controlling both the initial temperature and the reaction temperature can be effective in achieving good yields and selectivity. In an embodiment, the process can be at a temperature range of about -5 °C to about 15 °C. In another embodiment, the process can be conducted at an initial temperature of less than about 20 °C, less than about 15 °C, less than about 10°C, less than about 5 °C, or less than about 0 °C. The initial temperature can be as low a temperature as allowed by the propargyl solution without causing the solution to freeze. The initial temperature can be as low as -40 °C. The reaction temperature after addition of bromine to the propargyl reaction solution can be controlled as well. The temperature can be less than 50°C, less than about 40°C, less than about 35 °C, less than about 30 °C, or less than about 20°C. The temperature of the reaction can be above -10°C, above about 0 °C, above about 5 °C, or above about 10 °C. The

temperature of the reaction can be conducted between -5°C and about 50 °C, between about -5 °C and 40 °C, between about 5 °C and about 40 °C, or between about 10 °C to about 35 °C.

[0034] The disclosure can also include a step of quenching with a base. During initial efforts to prepare DBAA from propargyl alcohol with elemental bromine, subsequent work up steps without a base quench led to product loss and decreases in purity. An additional step in the process can then include quenching the reaction with a base. The base can be any base suitable for quenching reactions with potential HBr species, including ammonia, amines or other organic bases, and aqueous base solutions. The aqueous base solutions can include hydroxide, carbonate, or bicarbonate salts, including alkali hydroxides, alkaline earth hydroxides, alkali carbonates, alkaline earth carbonates, alkali bicarbonates, and alkaline earth bicarbonates. The terms hydroxide, carbonate, and bicarbonate are meant to reference the inorganic metal salt or base, where the hydroxyl, carbonate, or bicarbonate anion is accompanied by an inorganic counterion, i.e. a cation, such as sodium, potassium, calcium, ammonium, and the like. The amount of base required to quench the reaction can be the amount required to make the solution pH greater than about pH 7, greater than about pH 7.5, or greater than about pH 8. The solution can be treated until the pH is about 9 or greater, or the pH is about 10 or greater. The strength of the base solution can be any solution concentration that can convert the solution to the desired basic pH.

[0035] For the addition of the two bromines across the carbon-carbon triple bond, two isomers are possible, for the *trans* (or *E*-) and the *cis* (or *Z*-) isomers. Both the *trans* (or *E*-) and the *cis* (or *Z*-) isomers of DBAA have been reported in the literature. NMR results have been reported by K. Schuh and F. Glorius in *Synthesis*, 2007 (15), 2297-2306. See also Kodomari et al., *Bull. Chem. Soc. Jpn.* 1989, 62, 4053-4054. The isomer ratios in Schuh et al were 44:56. From the disclosure of Schuh and Glorius and the NMR analysis of DBAA produced as described below, it appears that the DBAA produced as described below and disclosure herein contains more than 95% of the *E*-isomer and a minor amount of the *Z*-isomer.

[0036] The disclosure then also provides for a 2,3-dibromo-2-propen-1-ol product having a very high *E* isomer content. The disclosure can include a 2,3-dibromo-2-propen-1-ol having an *E* isomer content of at least 90%. The *trans* (*E*-) isomer content can be at least 95%, at least 96%, or at least 97% or at least 98%, wherein the % is percent weight of isomer versus total DBAA. The disclosure can also include a process for preparing an isomerically enriched 2,3-dibromo-2-propen-1-ol, wherein propargyl alcohol is reacted with elemental bromine in an aqueous solution to yields greater than 95:5 *trans:cis* isomer (i.e. *E:Z* isomer ratio).

Alternatively, the disclosure can also include a process for preparing an isomerically enriched 2,3-dibromo-2-propen-1-ol, wherein propargyl alcohol is reacted with elemental bromine in the absence of graphite to yield greater than 90:10 *trans:cis* isomer, or greater than 95:5 *trans:cis*. The isomerically enriched DBAA can be greater than 96:4, greater than 97:3, or greater than 98:2.

[0037] The disclosure provides for processes that achieve very high yields of DBAA from propargyl alcohol. As will be noted below, the reaction product, DBAA, is an organic liquid separates from the aqueous base neutralization. This allows for the neat organic product to be separated from the water and collected. Crude yields of the neat liquid achieve greater than 95% of the mass for the crude reaction material. The disclosure includes a product yield of DBAA (cis and trans) of at least 90%, at least 92%, at least 94% or at least 95%.

EXAMPLES - GENERAL

[0038] The following examples are presented for purposes of illustration, and are not intended to impose limitations on the scope of this disclosure. All percentages in the following examples are by weight unless otherwise noted.

[0039] Crude DBAA product from a neat reaction of propargyl alcohol and Br₂ without a basic quenching step was not stable; the color changed from light brown to dark brown over time, and the purity of the DBAA decreased as well. A small amount of HBr was formed in the process, and it is believed that the HBr was produced by a side reaction. The HBr reacted with DBAA to produce a side product, 1,2,3-tribromopropene (TBP). TBP was identified by GC/MS. Performing the reaction in the presence of solvent reduced TBP formation, and reaction at lower temperatures eliminated TBP formation. Lower reaction temperature and use of water as solvent seemed to reduce byproduct formation and resulted in higher purity product.

[0040] When a crude reaction mixture formed from a neat reaction of propargyl alcohol and Br₂ was quenched with aqueous sodium hydroxide, potassium carbonate or sodium carbonate solution, the resulting pH value of the solution was greater than 7. After the basic work-up, the DBAA product seemed stable and its color remained light. No HBr puff was observed after the basic, aqueous work-up. The basic work-up stopped further reaction of HBr with DBAA. However, reacting propargyl alcohol with Br₂ in the presence of aq. K₂CO₃ led to lower DBAA yield and formation of bromoform by-product.

[0041] Some conditions and results for Examples 1-19 are summarized in Table 1 and 2. The amounts reported for DBAA (E + Z isomers) and trans/cis ratio (i.e. E/Z) were determined by gas chromatography.

EXAMPLE 1

[0042] Propargyl alcohol (270 g) was cooled to less than 0 °C in a 1-L, 4-neck, jacketed, round-bottom reactor. Bromine (Br₂, 771 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reactor temperature at 5 to 7 °C for 5 hours. The reaction mixture was agitated at 5 to 7 °C for 20 minutes until the bromine color disappeared. The reaction mixture was quenched by pouring it into a 20% aq. potassium carbonate solution (150 g). Phase separation gave an organic phase (1038 g, bottom layer) and an aqueous phase (151 g). The organic phase was analyzed; the water content was 2.04% by Karl-Fisher analysis; the pH was 10 to 11 by pH paper.

EXAMPLE 2

[0043] Propargyl alcohol (140 g), dichloromethane (20 mL) and deionized water (35 g) were cooled to less than 0 °C in a 1-L, 4-neck, jacketed, round-bottom reactor. Br₂ (400 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reactor temperature at 5 to 7 °C. The bath temperature was initially set at -20 °C and then raised to -5 °C during the last 20% bromine addition. After the bromine addition finished, the bath temperature was set at 0 °C, and the reaction mixture was agitated for 20 minutes. During the 20 minutes, the reactor temperature dropped from 7 °C to 2 °C. K₂CO₃ (aq., 40%, 30 g) was added to mixture, and the mixture was stirred for 5 minutes. Phase separation gave 561 g organic phase and 63 g aqueous phase. The organic phase was stripped by a rotary evaporator and then by vacuum to give 528 g of light yellow oil.

EXAMPLE 3

[0044] Propargyl alcohol (140 g) and methanol (50 mL) were cooled to less than 0 °C in a 1-L, 4-neck, jacketed, round-bottom reactor. Br₂ (400 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reactor temperature at 3 to 5 °C. The bath temperature was initially set at -20 °C and gradually raised to -10 °C. After the bromine addition finished, the bath temperature was set at 0 °C, and the reaction mixture was agitated for 20 minutes. K₂CO₃ (aq., 20%, precooled to 0 to 5 °C, 75 g) was added and the mixture was warmed to 10 °C. Phase separation gave 571 g organic phase and 78 g aqueous phase. The organic phase was stripped by a rotary evaporator and then by vacuum to give 526 g of light yellow oil.

EXAMPLE 4

[0045] Propargyl alcohol (260 g) and NaCl solution (aq., 20%, 102 g) were cooled to less than -5°C in a 1-L, 4-neck, jacketed, round-bottom reactor. Br_2 (750 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reactor temperature at 5 to 7°C for 240 minutes. The bath temperature was initially set at -15°C and then gradually raised to 0°C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was warmed to 15°C and then transferred to a separation funnel. Phase separation gave 1009 g of organic phase and 100 g of aqueous phase. The organic phase was washed with NaOH (aq., 10%, 93 g) and NaCl (aq., 20%, 200 g) to give 982 g of DBAA product. Chlorobromoallyl alcohol was identified by GCMS as minor products when NaCl was used.

EXAMPLE 5

[0046] Propargyl alcohol (260 g) and NaBr (aq., 10%, 100 g) were cooled to less than -5°C in a 1-L, 4-neck, jacketed, round-bottom reactor. Br_2 (750 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reactor temperature at 5 to 7°C for 240 minutes. The bath temperature was initially set at -15°C and then gradually raised to 0°C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was warmed to 15°C . Phase separation gave 1016 g of organic phase and 94 g of aqueous phase. The organic phase was washed with water (100 g). The organic phase was then neutralized with NaOH (aq., 10%, 5 mL) and washed with NaCl (aq., 15%, 100 g) to give 1000 g of DBAA product.

TABLE 1¹

Example	Reaction Temperature	Solvent	Workup	% Yield ²	DBAA (E + Z)	trans/cis Ratio
1	$5-7^{\circ}\text{C}$	Neat	20% K_2CO_3	99.8	95.5	96.6:3.4
2	$5-7^{\circ}\text{C}$	$\text{CH}_2\text{Cl}_2/\text{H}_2\text{O}$	40% K_2CO_3	97.9	98.3	98.6:1.4
3	$3-5^{\circ}\text{C}$	MeOH	20% K_2CO_3	97.9	97.1	99.1:0.9
4	$5-7^{\circ}\text{C}$	20% NaCl	10% NaOH	98.2	94.1	99.1:0.9
5	$5-7^{\circ}\text{C}$	10% NaBr	10% NaOH	99.9	98.3	98.6:1.4

¹ Product was isolated by phase cut without further purification.

² Yield was calculated based on the weight of the obtained product relative to the theoretical weight, without adjustment for product purity.

EXAMPLE 6

[0047] Propargyl alcohol (260 g) and NaBr solution (aq., 10%, 100 g) were cooled to -10°C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br_2 (749 g) was added via a Masterflex[®]

L/S pump at a rate to maintain the reaction temperature at 10 °C for 170 minutes. The bath temperature was initially set at -17 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was warmed to 5-10 °C and then quenched with NaOH (aq., 50%, 22 g) to pH 10-11. Phase separation gave 1008 g of organic phase and 124 g of aqueous phase.

EXAMPLE 7

[0048] Propargyl alcohol (260 g) and NaBr solution (aq., 10%, 100 g) were cooled to -10 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex® L/S pump at a rate to maintain the reaction temperature at 20 °C for 110 minutes. The bath temperature was initially set at -15 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was warmed to 5-10 °C and then quenched with NaOH (aq., 50%, 24 g) to pH 10-11. Phase separation gave 1006 g of organic phase and 127 g of aqueous phase.

EXAMPLE 8

[0049] Propargyl alcohol (260 g) and NaBr solution (aq., 10%, 100 g) were cooled to -10 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex® L/S pump at a rate to maintain the reaction temperature at 5 °C for 225 minutes. The bath temperature was initially set at -17 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was warmed to 5-10 °C and then quenched with NaOH (aq., 50%, 26 g) to pH 10-11. Phase separation gave 1001 g of organic phase and 134 g of aqueous phase.

EXAMPLE 9

[0050] Propargyl alcohol (260 g) and NaBr solution (prepared from Wellbrom® 12.4, aq., 10%, 100 g) were cooled to -10 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex® L/S pump at a rate to maintain the reaction temperature at 5 °C for 200 minutes. The bath temperature was initially set at -19 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was warmed to 5-10 °C and then quenched with NaOH (aq., 50%, 27 g) to pH 10-11. Phase separation gave 995 g of organic phase and 137 g of aqueous phase.

EXAMPLE 10

[0051] Propargyl alcohol (260 g) and NaBr solution (aq., 10%, 100 g) were cooled to -10 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex® L/S pump at a rate to maintain the reaction temperature at 30 °C for 82 minutes. The bath temperature was initially set at -15 °C and then gradually raised to 0 °C during the last 10%

bromine addition. After the bromine addition finished, the reaction mixture was cooled to 20 °C and then quenched with NaOH (aq., 50%, 27 g) to pH 10-11. Phase separation gave 999 g of organic phase and 135 g of aqueous phase.

EXAMPLE 11

[0052] Propargyl alcohol (260 g) and NaBr solution (aq., 20%, 100 g) were cooled to –10 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at 20 °C for 110 minutes. The bath temperature was initially set at –15 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to 15 °C and then quenched with NaOH (aq., 50%, 26 g) to pH 10-11. Phase separation gave 996 g of organic phase and 136 g of aqueous phase.

EXAMPLE 12

[0053] Propargyl alcohol (260 g) and DI water (100 g) were cooled to –20 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at 20 °C for 105 minutes. The bath temperature was initially set at –15 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to 15 °C and then quenched with NaOH (aq., 50%, 30.5 g) to pH 10-11. Phase separation gave 994 g of pale yellow-colored organic phase and 151 g of aqueous phase.

EXAMPLE 13

[0054] Propargyl alcohol (261 g) was cooled to –20 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at 20 °C for 110 minutes. The bath temperature was initially set at –15 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to 15 °C and then quenched with NaOH (aq., 50%, 21.5 g) to pH 10-11. DI water (140 g) was added. Phase separation gave 1,000 g of brown-colored organic phase.

EXAMPLE 14

[0055] Propargyl alcohol (260 g) and DI water (102 g) were cooled to –20 °C in a 3-L, 5-neck, jacketed, round-bottom reactor. Br₂ (749 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at 30 °C for 90 minutes. The bath temperature was initially set at –15 °C and then gradually raised to 0 °C during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to 15 °C and then

quenched with NaOH (aq., 50%, 30 g) to pH 10-11. Phase separation gave 994 g of honey-colored organic phase and 148 g of aqueous phase.

EXAMPLE 15

[0056] Propargyl alcohol (260 g) and 100 g DI water were cooled to $-20\text{ }^{\circ}\text{C}$ in a 3-L, 5-neck, jacketed, round-bottom reactor. Br_2 (749 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at $10\text{ }^{\circ}\text{C}$ for 180 minutes. The bath temperature was initially set at $-15\text{ }^{\circ}\text{C}$ and then gradually raised to $0\text{ }^{\circ}\text{C}$ during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to $15\text{ }^{\circ}\text{C}$ and then quenched with NaOH (aq., 50%, 29 g) to pH 10-11. Phase separation gave 997 g of honey-colored organic phase and 135 g aqueous phase.

EXAMPLE 16

[0057] Propargyl alcohol (261 g) and DI water (99 g) were cooled to $-20\text{ }^{\circ}\text{C}$ in a 3-L, 5-neck, jacketed, round-bottom reactor. Br_2 (750 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at $35\text{ }^{\circ}\text{C}$ for 60 minutes. The bath temperature was initially set at $-15\text{ }^{\circ}\text{C}$ and then gradually raised to $0\text{ }^{\circ}\text{C}$ during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to $15\text{ }^{\circ}\text{C}$ and then quenched with NaOH (aq., 50%, 38 g) to pH 10-11. Phase separation gave 989 g of amber-colored organic phase and 155 g of aqueous phase.

EXAMPLE 17

[0058] Propargyl alcohol (520 g) and DI water (204 g) were cooled to $-20\text{ }^{\circ}\text{C}$ in a 3-L, 5-neck, jacketed, round-bottom reactor. Br_2 (1499 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at $20\text{ }^{\circ}\text{C}$ for 120 minutes. The bath temperature was initially set at $-15\text{ }^{\circ}\text{C}$ and then gradually raised to $0\text{ }^{\circ}\text{C}$ during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to $15\text{ }^{\circ}\text{C}$ and then quenched with NaOH (aq., 50%, 57 g) to pH 10-11. Phase separation gave 989 g of amber-colored organic phase and 300 g of aqueous phase.

EXAMPLE 18

[0059] Propargyl alcohol (521 g) and DI water (102 g) were cooled to $-20\text{ }^{\circ}\text{C}$ in a 3-L, 5-neck, jacketed, round-bottom reactor. Br_2 (1,499 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at $25\text{ }^{\circ}\text{C}$ for 120 minutes. The bath temperature was initially set at $-15\text{ }^{\circ}\text{C}$ and then gradually raised to $0\text{ }^{\circ}\text{C}$ during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to $15\text{ }^{\circ}\text{C}$ and then quenched with NaOH (aq., 50%, 71 g) to pH 10-11. Aqueous 10% Na_2SO_3 was then

added and the reaction mixture was stirred for 10 minutes. Phase separation gave 1972 g of brown organic phase and 230 g of black-colored aqueous phase.

EXAMPLE 19

[0060] Propargyl alcohol (520 g) and DI water (101 g) were cooled to $-20\text{ }^{\circ}\text{C}$ in a 3-L, 5-neck, jacketed, round-bottom reactor. Br_2 (1,498 g) was added via a Masterflex[®] L/S pump at a rate to maintain the reaction temperature at $20\text{ }^{\circ}\text{C}$ for 180 minutes. The bath temperature was initially set at $-15\text{ }^{\circ}\text{C}$ and then gradually raised to $0\text{ }^{\circ}\text{C}$ during the last 10% bromine addition. After the bromine addition finished, the reaction mixture was cooled to $15\text{ }^{\circ}\text{C}$ and then quenched with NaOH (aq., 50%, 60.4 g) to pH 10-11. Phase separation gave 1981 g of amber-colored organic phase and 195 g of brown-colored aqueous phase.

TABLE 2¹

Example	Reaction Temperature	Solvent	Workup	% Yield ²	DBAA (E + Z)	trans/cis Ratio
6	$10\text{ }^{\circ}\text{C}$	10% NaBr	50% NaOH	100	97.8	98.9:1.1
7	$20\text{ }^{\circ}\text{C}$	10% NaBr	50% NaOH	100	97.4	98.8:1.2
8	$5\text{ }^{\circ}\text{C}$	10% NaBr	50% NaOH	100	98.2	98.9:1.1
9	$5\text{ }^{\circ}\text{C}$	10% NaBr ³	50% NaOH	99.4	97.7	99.0:1.0
10	$30\text{ }^{\circ}\text{C}$	10% NaBr	50% NaOH	99.8	97.7	98.9:1.1
11	$20\text{ }^{\circ}\text{C}$	20% NaBr	50% NaOH	99.5	98.0	99.2:0.8
12	$20\text{ }^{\circ}\text{C}$	Water	50% NaOH	98.5	96.7	98.8:1.2
13	$20\text{ }^{\circ}\text{C}$	Neat	50% NaOH	99.0	93.5	97.2:2.8
14	$30\text{ }^{\circ}\text{C}$	Water	50% NaOH	98.6	95.9	97.9:2.1
15	$10\text{ }^{\circ}\text{C}$	Water	50% NaOH	98.8	96.3	98.7:1.3
16	$35\text{ }^{\circ}\text{C}$	Water	50% NaOH	97.9	95.9	98.1:1.9
17 ⁴	$20\text{ }^{\circ}\text{C}$	Water	50% NaOH	97.7	95.5	98.6:1.4
18 ⁴	$25\text{ }^{\circ}\text{C}$	Water	50% NaOH, 10% Na_2SO_3	97.6	97.0	99.1:0.9
19 ⁴	$20\text{ }^{\circ}\text{C}$	Water	50% NaOH	98.2	96.6	98.5:1.5

¹ Typical reaction size was 1 kg. Product was isolated by phase cut without further purification.

² Yield was calculated based on the weight of the obtained product relative to the theoretical weight, without adjustment for product purity.

³ Wellbrom[®] 12.4 was used to prepare 10% NaBr.

⁴ Reaction was run in 2x typical scale.

EMBODIMENTS

[0061] Additionally or alternately, the disclosure can include one or more of the following embodiments.

[0062] Embodiment 1. A process for preparing 2,3-dibromo-2-propen-1-ol, which process comprises contacting 2-propyn-1-ol and elemental bromine at a temperature in the range of about -5°C about 15°C .

[0063] Embodiment 2. A process for preparing 2,3-dibromo-2-propen-1-ol, comprising preparing a 2-propyn-1-ol solution, wherein the 2-propyn-1-ol solution comprises no solvent or a protic solvent, contacting the 2-propyn-1-ol solution with elemental bromine, and quenching the reaction with a base, to produce 2,3-dibromo-2-propen-1-ol.

[0064] Embodiment 3. A process for preparing the 2,3-dibromo-2-propen-1-ol, wherein the 2,3-dibromo-2-propen-1-ol has an *E* isomer content of at least 95%, and wherein the process comprises reacting propargyl alcohol with elemental bromine in the absence of graphite.

[0065] Embodiment 4. The processes of one of the previous embodiments, wherein the 2-propyn-1-ol can be dissolved in a protic solvent, or can be dissolved in an aqueous solvent, or can be neat. The protic solvent include an alcohol, can include a C_1 to C_4 alcohol, can include water or can include an alkali metal salt and water, particularly an alkali bromide salt.

[0066] Embodiment 5. The processes of one of the previous embodiments, wherein the reaction can be subsequently treated with a basic aqueous solution. The basic aqueous solution comprises a hydroxide, carbonate or bicarbonate solution.

[0067] Embodiment 6. The processes of one of the previous embodiments, wherein the 2,3-dibromo-2-propen-1-ol product has an *E* isomer content of at least 95% weight., at least 96% weight, or at least 98% weight.

[0068] Embodiment 7. The processes of one of the previous embodiments, wherein the reaction can be conducted at an initial temperature of less than 10°C .

[0069] Embodiment 4. The processes of one of the previous embodiments, wherein the reaction can be conducted at a temperature below 40°C .

[0070] It is to be understood that the embodiments and claims disclosed herein are not limited in their application to the details of construction and arrangement of the components set forth in the description and illustrated in the drawings. Rather, the description and the drawings provide examples of the embodiments envisioned. The embodiments and claims disclosed herein are further capable of other embodiments and of being practiced and carried out in various ways. Also, it is to be understood that the phraseology and terminology

employed herein are for the purposes of description and should not be regarded as limiting the claims.

[0071] Accordingly, those skilled in the art will appreciate that the conception upon which the application and claims are based can be readily utilized as a basis for the design of other structures, methods, and systems for carrying out the several purposes of the embodiments and claims presented in this application. It is important, therefore, that the claims be regarded as including such equivalent constructions.

What is claimed is:

1. A process for preparing 2,3-dibromo-2-propen-1-ol, which process comprises contacting 2-propyn-1-ol and elemental bromine at a temperature in the range of about -5°C about 15°C .
2. The process of claim 1, wherein 2-propyn-1-ol is dissolved in a protic solvent prior to contacting with elemental bromine.
3. The process of claim 1, wherein the 2-propyn-1-ol contacted with the elemental bromine comprises a neat solution.
4. The process of any of claims 1, 2 or 3, wherein the reaction is subsequently treated with a basic aqueous solution.
5. The process of claim 4, wherein the basic aqueous solution comprises a hydroxide, carbonate or bicarbonate solution.
6. The process of claim 1, wherein the reaction is conducted at an initial temperature of less than 10°C .
7. The process of Claim 1, wherein the 2,3-dibromo-2-propen-1-ol product has an *E* isomer content of at least 95% weight.
8. The process of claim 2, wherein the protic solvent is an aqueous solution.
9. The process of claim 2, wherein the protic solution comprises an alkali metal salt and water.
10. A process for preparing 2,3-dibromo-2-propen-1-ol, comprising
preparing a 2-propyn-1-ol solution, wherein the 2-propyn-1-ol solution comprises no solvent or a protic solvent
contacting the 2-propyn-1-ol solution with elemental bromine, and
quenching the reaction with a base,
to produce 2,3-dibromo-2-propen-1-ol.
11. The process of claim 10, wherein the 2-propyn-1-ol is neat.

12. The process of claim 10, wherein the 2-propyn-1-ol solution comprises a protic solvent.
13. The process of claim 12, wherein the protic solvent comprising a C₁ to C₄ alcohol.
14. The process of Claim 10, wherein the 2-propyn-1-ol solution comprises an aqueous solvent.
15. The process of claim 14, wherein the aqueous solvent comprises water and an alkali bromide salt.
16. The process of any of claims 10-15, wherein the reaction is conducted at a temperature below 40°C.
17. The process of any of claims 10-15, wherein the reaction is conducted at an initial temperature below 15 °C.
18. The process of any of claims 10-15, wherein quenching the reaction with a base comprises quenching with a basic aqueous solution.
19. The process of claim 18, wherein the basic aqueous solution comprises a hydroxide, carbonate or bicarbonate solution.
20. A process for preparing the 2,3-dibromo-2-propen-1-ol, wherein the 2,3-dibromo-2-propen-1-ol has an *E* isomer content of at least 95%, and wherein the process comprises reacting propargyl alcohol with elemental bromine in the absence of graphite.
21. The process of claim 20, wherein the 2-propyn-1-ol is neat.
22. The process of claim 20, wherein the 2-propyn-1-ol is dissolved in a protic solvent.
23. The process of Claim 20, wherein the 2-propyn-1-ol is dissolved in an aqueous solvent.
24. A composition comprising 2,3-dibromo-2-propen-1-ol, having an *E* isomer content of at least 95%.
25. The compound of Claim 20, having an *E* isomer content of at least 96%.

26. The compound of Claim 20, having an *E* isomer content of at least 98%.
27. The compound of Claim 20, prepared by any of the processes of Claim 1, 10, or 20.

INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. C07C17/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C07C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 23 44 254 A1 (GAF CORP) 14 March 1974 (1974-03-14) examples 7,11	1-27
X	----- US 3 932 181 A (RAY-CHAUDHURI DILIP K ET AL) 13 January 1976 (1976-01-13) cited in the application STEP I; example V -----	1,6,7, 20,24-27



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Bergmeier, Martin

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2018/053401

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 2344254	A1	14-03-1974	NONE

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