

TITLE OF INVENTION

AZEOTROPE-LIKE COMPOSITIONS OF
HFO-E-1,3,4,4,4-PENTAFLUORO-3-TRIFLUOROMETHYL-1-BUTENE
5 AND E-1-CHLORO-3,3,3-TRIFLUOROPROPENE AND USES THEREOF

BACKGROUND OF THE INVENTION**Field of the Disclosure**

The present disclosure relates to azeotrope-like compositions of
10 HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-
3,3,3-trifluoropropene.

Description of Related Art

Many industries have been working for the past few decades to find
15 replacements for the ozone depleting chlorofluorocarbons (CFCs) and
hydrochlorofluorocarbons (HCFCs). The CFCs and HCFCs have been
employed in a wide range of applications, including their use as aerosol
propellants, refrigerants, cleaning agents, expansion agents for
thermoplastic and thermoset foams, heat transfer media, gaseous
20 dielectrics, fire extinguishing and suppression agents, power cycle working
fluids, polymerization media, particulate removal fluids, carrier fluids,
buffing abrasive agents, and displacement drying agents. In the search
for replacements for these versatile compounds, many industries have
turned to the use of hydrofluorocarbons (HFCs).

25 The HFCs do not contribute to the destruction of stratospheric
ozone, but are of concern due to their contribution to the "greenhouse
effect", i.e., they contribute to global warming. As a result of their
contribution to global warming, the HFCs have come under scrutiny, and
their widespread use may also be limited in the future.

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SUMMARY OF THE INVENTION

Thus, there is a need for compositions that do not contribute to the destruction of stratospheric ozone and also have low global warming potentials (GWPs). Certain hydrofluoroolefins, such as HFO-E-1,3,4,4,4-pentafluoro-3-trifluoromethyl-1 butene ($(\text{CF}_3)_2\text{CFCH}=\text{CHF}$, trans-HFO-1438ez,

E-HFO-1438ez, E-1438ez) are believed to meet both goals. This disclosure provides a composition consisting essentially of (a) HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and (b) E-1-Chloro-3,3,3-trifluoropropene ; wherein the E-1-Chloro-3,3,3-trifluoropropene is present in an effective amount to form an azeotrope-like mixture with HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene.

BRIEF SUMMARY OF THE DRAWINGS

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FIG. 1 - FIG. 1 is a graphical representation of an azeotrope-like composition of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene at a temperature of about 27.8 °C.

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DETAILED DESCRIPTION OF THE INVENTION

In many applications, the use of a pure single component or an azeotropic or azeotrope-like mixture is desirable. For example, when a blowing agent composition (also known as foam expansion agents or foam expansion compositions) is not a pure single component or an azeotropic or azeotrope-like mixture, the composition may change during its application in the foam forming process. Such change in composition could detrimentally affect processing or cause poor performance in the application. Also, in refrigeration applications, a refrigerant is often lost during operation through leaks in shaft seals, hose connections, soldered joints and broken lines. In addition, the refrigerant may be released to the atmosphere during maintenance procedures on refrigeration equipment. If the refrigerant is not a pure single component or an azeotropic or azeotrope-like composition, the refrigerant composition may change when

leaked or discharged to the atmosphere from the refrigeration equipment. The change in refrigerant composition may cause the refrigerant to become flammable or to have poor refrigeration performance. Accordingly, there is a need for using azeotropic or azeotrope-like mixtures in these and other applications, for example azeotropic or azeotrope-like mixtures containing HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Before addressing details of embodiments described below, some terms are defined or clarified.

As used herein, the terms “comprises,” “comprising,” “includes,” “including,” “has,” “having” or any other variation thereof, are intended to cover a non-exclusive inclusion. For example, a process, method, article, or apparatus that comprises a list of elements is not necessarily limited to only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. Further, unless expressly stated to the contrary, “or” refers to an inclusive or and not to an exclusive or. For example, a condition A or B is satisfied by any one of the following: A is true (or present) and B is false (or not present), A is false (or not present) and B is true (or present), and both A and B are true (or present).

Also, use of “a” or “an” are employed to describe elements and components described herein. This is done merely for convenience and to give a general sense of the scope of the invention. This description should be read to include one or at least one and the singular also includes the plural unless it is obvious that it is meant otherwise.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the present invention, suitable methods and materials are described below. All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety, unless a particular passage is

cited. In case of conflict, the present specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

When an amount, concentration, or other value or parameter is given as either a range, preferred range or a list of upper preferable values and/or lower preferable values, this is to be understood as specifically disclosing all ranges formed from any pair of any upper range limit or preferred value and any lower range limit or preferred value, regardless of whether ranges are separately disclosed. Where a range of numerical values is recited herein, unless otherwise stated, the range is intended to include the endpoints thereof, and all integers and fractions within the range.

This application includes compositions consisting essentially of (a) HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene; wherein the E-1-Chloro-3,3,3-trifluoropropene is present in an effective amount to form an azeotrope-like mixture with HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene.

By effective amount is meant an amount of E-1-Chloro-3,3,3-trifluoropropene, which, when combined with HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene, results in the formation of an azeotrope-like mixture. This definition includes the amounts of each component, which amounts may vary depending on the pressure applied to the composition so long as the azeotrope-like compositions continue to exist at the different pressures, but with possible different boiling points. Therefore, effective amount includes the amounts, such as may be expressed in weight or mole percentages, of each component of the compositions of the instant invention which form azeotrope-like compositions at temperatures or pressures other than as described herein.

As recognized in the art, an azeotropic composition is an admixture of two or more different components which, when in liquid form under a given pressure, will boil at a substantially constant temperature, which temperature may be higher or lower than the boiling temperatures of the individual components, and which will provide a vapor composition

essentially identical to the overall liquid composition undergoing boiling.
(see, e.g., M. F. Doherty and M.F. Malone, Conceptual Design of
Distillation Systems, McGraw-Hill (New York), 2001, 185-186, 351-359).

Accordingly, the essential features of an azeotropic composition are
5 that at a given pressure, the boiling point of the liquid composition is fixed
and that the composition of the vapor above the boiling composition is
essentially that of the overall boiling liquid composition (i.e., no
fractionation of the components of the liquid composition takes place). It is
also recognized in the art that both the boiling point and the weight
10 percentages of each component of the azeotropic composition may
change when the azeotropic composition is subjected to boiling at different
pressures. Thus, an azeotropic composition may be defined in terms of
the unique relationship that exists among the components or in terms of
the compositional ranges of the components or in terms of exact weight
15 percentages of each component of the composition characterized by a
fixed boiling point at a specified pressure.

For the purpose of this invention, an azeotrope-like composition
means a composition that behaves like an azeotropic composition (i.e.,
has constant boiling characteristics or a tendency not to fractionate upon
20 boiling or evaporation). Hence, during boiling or evaporation, the vapor
and liquid compositions, if they change at all, change only to a minimal or
negligible extent. This is to be contrasted with non-azeotrope-like
compositions in which during boiling or evaporation, the vapor and liquid
compositions change to a substantial degree.

25 Additionally, azeotrope-like compositions exhibit dew point pressure
and bubble point pressure with virtually no pressure differential. That is to
say that the difference in the dew point pressure and bubble point
pressure at a given temperature will be a small value. In this invention,
compositions with a difference in dew point pressure and bubble point
30 pressure of less than or equal to 5 percent (based upon the bubble point
pressure) is considered to be azeotrope-like.

It is recognized in this field that when the relative volatility of a
system approaches 1.0, the system is defined as forming an azeotropic or
azeotrope-like composition. Relative volatility is the ratio of the volatility of

component 1 to the volatility of component 2. The ratio of the mole fraction of a component in vapor to that in liquid is the volatility of the component.

To determine the relative volatility of any two compounds, a method known as the PTx method can be used. The vapor-liquid equilibrium (VLE), and hence relative volatility, can be determined either isothermally or isobarically. The isothermal method requires measurement of the total pressure of mixtures of known composition at constant temperature. In this procedure, the total absolute pressure in a cell of known volume is measured at a constant temperature for various compositions of the two compounds. The isobaric method requires measurement of the temperature of mixtures of known composition at constant pressure. In this procedure, the temperature in a cell of known volume is measured at a constant pressure for various compositions of the two compounds. Use of the PTx Method is described in detail in "Phase Equilibrium in Process Design", Wiley-Interscience Publisher, 1970, written by Harold R. Null, on pages 124 to 126.

These measurements can be converted into equilibrium vapor and liquid compositions in the PTx cell by using an activity coefficient equation model, such as the Non-Random, Two-Liquid (NRTL) equation, to represent liquid phase nonidealities. Use of an activity coefficient equation, such as the NRTL equation is described in detail in "The Properties of Gases and Liquids," 4th edition, published by McGraw Hill, written by Reid, Prausnitz and Poling, on pages 241 to 387, and in "Phase Equilibria in Chemical Engineering," published by Butterworth Publishers, 1985, written by Stanley M. Walas, pages 165 to 244. Without wishing to be bound by any theory or explanation, it is believed that the NRTL equation, together with the PTx cell data, can sufficiently predict the relative volatilities of the HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene compositions of the present invention and can therefore predict the behavior of these mixtures in multi-stage separation equipment such as distillation columns.

It was found through experiments that HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene form azeotrope-like compositions.

To determine the relative volatility of this binary pair, the PTx method described above was used. The pressure in a PTx cell of known volume was measured at constant temperature for various binary compositions. These measurements were then reduced to equilibrium vapor and liquid compositions in the cell using the NRTL equation.

The pressures measured versus the compositions in the PTx cell for HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene mixtures are shown in FIG. 1, which graphically illustrates the formation of azeotrope-like compositions consisting essentially of 1-44 mole % HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and 56-99 mole % E-1-Chloro-3,3,3-trifluoropropene at 27.8 °C and pressures ranging from about 18 to 21 psia, and also illustrates the formation of azeotrope-like compositions consisting essentially of 84-99 mole % HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and 1-16 mole % E-1-Chloro-3,3,3-trifluoropropene at 27.8 °C and pressures ranging from about 13 to 14 psia .

According to calculation, azeotrope-like compositions consisting essentially of 1-99 mole % HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and 1-99 mole % E-1-Chloro-3,3,3-trifluoropropene are formed at temperatures ranging from about -40 °C to about 140 °C (i.e., over this temperature range, the difference in dew point pressure and bubble point pressure of the composition at a particular temperature is less than or equal to 5 percent (based upon the bubble point pressure)).

Some embodiments of azeotrope-like compositions are listed in Table 1

Table 1 Azeotrope-like compositions

COMPONENTS	T (°C)	Mole Percentage Range
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	- 40	1 – 28 / 72 -99 94 – 99 / 1 - 6
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	- 20	1 – 29 / 71 – 99 93 – 99 / 1 -7
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	0	1 – 32 / 68 – 99 91 – 99 / 1 - 9
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	20	1 – 39 / 61 – 99 87 – 99 / 1 - 13
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	40	1 – 53 / 47 – 99 77 – 99 / 1 - 23
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	60	1 – 99 / 1 - 99
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	80	1 – 99 / 1 - 99
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	100	1 – 99 / 1 - 99
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	120	1 – 99 / 1 - 99
HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene / E-1-Chloro-3,3,3-trifluoropropene	140	1 – 99 / 1 - 99

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The azeotrope-like compositions of the present invention can be prepared by any convenient method including mixing or combining the desired amounts. In one embodiment of this invention, an azeotrope-like composition can be prepared by weighing the desired component amounts and thereafter combining them in an appropriate container.

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The azeotrope-like compositions of the present invention can be used in a wide range of applications, including their use as aerosol propellants, refrigerants, solvents, cleaning agents, blowing agents (foam expansion agents) for thermoplastic and thermoset foams, heat transfer media, gaseous dielectrics, fire extinguishing and suppression agents, power cycle working fluids, polymerization media, particulate removal

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fluids, carrier fluids, buffing abrasive agents, and displacement drying agents.

One embodiment of this invention provides a process for preparing a thermoplastic or thermoset foam. The process comprises using an azeotrope-like composition as a blowing agent, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Another embodiment of this invention provides a process for producing refrigeration. The process comprises condensing an azeotrope-like composition and thereafter evaporating said azeotrope-like composition in the vicinity of the body to be cooled, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Another embodiment of this invention provides a process using an azeotrope-like composition as a solvent, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Another embodiment of this invention provides a process for producing an aerosol product. The process comprises using an azeotrope-like composition as a propellant, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Another embodiment of this invention provides a process using an azeotrope-like composition as a heat transfer media, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Another embodiment of this invention provides a process for extinguishing or suppressing a fire. The process comprises using an azeotrope-like composition as a fire extinguishing or suppression agent, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

Another embodiment of this invention provides a process using an azeotrope-like composition as dielectrics, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

CLAIMS

1. A composition consisting essentially of:
 - (a) HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene; and
 - 5 (b) E-1-Chloro-3,3,3-trifluoropropene; wherein the E-1-Chloro-3,3,3-trifluoropropene is present in an effective amount to form an azeotrope-like combination with the HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene.
- 10 2. A process for preparing a thermoplastic or thermoset foam comprising using an azeotrope-like composition as a blowing agent, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.
- 15 3. A process for producing refrigeration comprising condensing an azeotrope-like composition and thereafter evaporating said azeotrope-like composition in the vicinity of the body to be cooled, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.
- 20 4. A process comprising using an azeotrope-like composition as a solvent, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.
- 25 5. A process for producing an aerosol product comprising using an azeotrope-like composition as a propellant, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.
- 30 6. A process comprising using an azeotrope-like composition as a heat transfer media, wherein said azeotrope-like composition consists essentially of HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.
7. A process for extinguishing or suppressing a fire comprising using an azeotrope-like composition as a fire extinguishing or suppression agent, wherein said azeotrope-like composition consists essentially of

HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

8. A process comprising using an azeotrope-like composition as dielectrics, wherein said azeotrope-like composition consists essentially of
- 5 HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and E-1-Chloro-3,3,3-trifluoropropene.

9. A process according to Claim 2 in which said azeotrope-like composition consists essentially of 95-99 mole % HFO-E-1,3,4,4,4-Pentafluoro-3-trifluoromethyl-1-butene and 1-5 mole % E-1-Chloro-3,3,3-
- 10 trifluoropropene.