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Non- Halogenated, Non-Combustible, Non-Electrically Conductive, and Commercially Available Fluids

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Abstract: Liquids can be flammable, combustible or can be neither flammable nor combustible liquids. Liquids with flash points below 100 F, 37.8 degree Celsius are flammable liquids. Liquids with flash points at or above 100°F, 37.8 degree Celsius are known to be combustible liquids. The lower the flash point is the higher the flammability of the liquid. Some solutions and liquids can conduct an electrical current by producing ions. Solutions are ether electrolytes or non-electrolytes. Electrolyte solutions can conduct electrical current. On the contrary to electrolytes, non-electrolytes don't conduct an electrical current as they don't dissociate into ions in solution. A non-halogenated compound is a compound that doesn't contain a halogen element in their composition. This research is aimed to find a commercially available liquids and solutions that are non- halogenated, non-combustible, are liquids or in liquid-vapor equilibrium at ambient conditions, have a normal boiling point of ≥80°C, and aren't electrically conductive, and to determine whether some suggested chemical compounds would meet the criterion: chloroform, carbon tetrachloride, bromine, mercury, and 100% concentrated sulfuric acid. Possible classes of compounds that meets the criterion requested are inorganic compounds including acids, bases, and salts, organic compounds including hydrocarbons, alcohols, esters, amines, aldehydes, ketones, carboxylic acids, carbohydrates, amino acids and proteins, and lipids. Most inorganic solvents and soluble inorganic compounds are electrically conductive, and most of classes of organic solvents and organic compounds are either flammable or combustible. It was found that most of the suggested chemical compounds don't meet the criterion, and some chemical compounds meeting the criterion requested were identified.

Keywords: Inorganic Solvents, Non-Combustible Solvents, Non-Halogenated Solvents, Non-Conductive Solvents, Commercially Available, Solvents Meeting Certain Criterion

1. Introduction

A leading supplier, technology innovator of integrated products in Missouri, United States are looking for chemical compounds that meets a certain criterion: non- halogenated, aren't combustible, are liquid or in liquid-vapor equilibrium at ambient conditions, has a normal boiling point of ≥80°C, and aren't electrically conductive for their use [1].

Liquids that burn with extreme rapidity and ignite easily, are flammable and combustible liquids. The materials flash point determines the flammability of the liquid. The minimum temperature where a liquid form a vapor above its surface in concentration that it can be ignited is the flashpoint. The liquid doesn't burn, rather the vapor itself burns. The amount of vapor produced depends on the vapor pressure of that liquid. Flammable and combustible liquids become more hazardous at elevated temperatures than at room temperature. [2]

Halocarbons are hydrocarbons containing one or more halogen atoms (containing atoms of Group VIIA elements). Bromine, Chlorine, Iodine atoms are examples of halogens. Examples of halogenated hydrocarbon includes chloroform ($CHCl_3$), carbon tetrachloride (CCl_4), tetrachloroethylene (C_2Cl_4), 1-bromopropane (C_3H_7Br), and methylene chloride (CH_2Cl_2). Health and physical hazards are associated with the use of halogenated hydrocarbons. Physical hazards are due to the flammability of the low molecular weight compounds. Health hazards *a*ssociated with halogenated hydrocarbons depend on the specific chemical, duration of exposure, route of exposure and the airborne concentration. These compounds reduce amount of oxygen concentration in air, they act as asphyxiates. [3]

A halogenated compound is a compound that contains a halogen element; their composition would include molecules of group 7A elements, such as chlorine (Cl), bromine (Br), fluorine (F) and iodine (I). Examples for organic halogenated compounds: haloalkanes, haloalkenes, and halo aromatics such as acryl bromide, alkyl chloride, and vinylic iodide. Examples for organic halogenated compounds: hydrobromic acid, hydrobromic and hydroiodic acids. [4]

Liquids with flash points below 100 F, 37.8 degree Celsius are flammable liquids, and they are divided into Class IA, IB, and IC based on their boiling points and flash points. Liquids with boiling point below 100 F, and Flash point below 73 F, are class IA liquids, methyl ethyl ether, collodion, ethyl ether, pentane, chloroethane, diethyl ethyl ether, and pentene are some examples of class IA liquids. Liquids with boiling point at or above 100 F, and flash point below 73 F, are class IB liquids, acetone dichloroethane, isopropyl alcohol, acrolein, ethyl acetate, methyl alcohol, acrylonitrile, ethyl alcohol methyl ethyl ketone, are some examples of class IB liquids. Liquids with boiling point below 100 F, and flash point at or above 73 F, are class IC liquids, amyl acetate, chloro-hexane, styrene, amyl alcohol, naphtha, and turpentine, are some examples of class IC liquids.

Liquids with flash points at or above 100°F, 37.8 degree Celsius are Combustible liquids, and it's divided into Class II and Class IIIA based on their flash point ranges. Liquids with Flash point at or above 100 F and below 140 F are called Class II liquids: acetic acid (glacial), mineral spirits, camphor oil, and methyl lactate are some examples. Liquids with flash point at or above 140 F and below 200 F are called Class IIIA fluids: benzaldehyde, formic acid, phenol, carbolic acid, and furfuryl alcohol are some examples. [5]

The lower the flash point is the higher the flammability of the liquid. Liquids with flash points below 37.8 degree Celsius are flammable liquids, and liquids with flash points above 37.8 degree Celsius are combustible liquids. Combustible substances would produce heat and light upon the burning of the substance in air, kerosene, oils, petrol are examples of combustible liquids. Non-combustible substance are substances that wouldn't produce light and heat the burning of the substance. [6] Hydrocarbons, compounds that contain carbon and hydrogen atoms are combustible materials, they react with oxygen to produce carbon dioxide, heat, and water when burnet. [7] Most organic solvents are either flammable or combustible materials. [8] Benzyl alcohol, vinyl bromide, benzene, and anisole are examples of organic solvents. [9]

Amino acids are compounds that contain both carboxyl (-COOH) and amine groups (-NH_2) in the same molecule. Twenty amino acids are used and formed by living organisms. Structure of amino acid are shown, both are correct structures. Some amino acids solutions are known not to be combustible. [10, 11]

Sugars are compounds that consists various numbers of carbon, hydrogen, and oxygen atoms bound together with a covalent bond. They are classified into monosaccharides, disaccharides, and polysaccharides. Monosaccharides are simple sugars consisting of only one molecule, fructose, glucose, galactose are examples of monosaccharides. Complex sugars or disaccharides consists of two molecules linked in either alpha or beta positions, maltose, lactose and sucrose are examples of disaccharides. Polysaccharides consists of a number of sugar molecules bond together with covalent bonds, dextrin, cellulose, and starch are examples of polysaccharides. [12, 13]

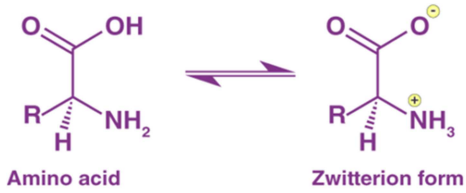


***Figure 1. Chemical** structure for an amino acid.*

Some solutions and liquids have the ability to conduct an electrical current. Electrolyte solutions are able to conduct electrical current and is either strong or weak electrolytes. In a strong electrolytic solution, all solute species are existing as ions in solution, good conductors of an electrical current. In a weak electrolytic solution, some solute species are existing as ions and others as undissociated molecules, poor conductor of an electrical current. On the contrary to electrolytes, non-electrolytes don't conduct an electrical current as they don't dissociate into ions in solution.

Magnesium nitrate is an example of a strong electrolytic solution, hydrofluoric acid is an example of a weak electrolyte, and ethyl alcohol is an example of a non-electrolyte solution. [14]

$$\mathrm{Mg(NO_3)_2}(s) \xrightarrow[\text{Dissociation}]{\mathrm{H_2O}} \mathrm{Mg^{2+}}(aq) + 2\mathrm{NO_3^-}(aq)$$

$$\mathrm{HF}(aq) \underset{\text{Recombination}}{\overset{\text{Dissociation}}{\rightleftarrows}} \mathrm{H^+}(aq) + \mathrm{F^-}(aq)$$

$$\mathrm{CH_4O}(l) \xrightarrow{\mathrm{H_2O}} \mathrm{CH_4O}(aq)$$

***Figure 2.** Strong, weak, and non-electrolyte behavior in aqueous solutions.*

Inorganic compounds are known to be non-volatile, and non-flammable in contrast to organic compounds. A non-aqueous inorganic solvent isn't an organic solvent. Examples for such inorganic solvents are: sulfuryl chloride fluoride, liquid ammonia, liquid sulfur dioxide, bromine pentafluoride, sulfuryl chloride and phosphoryl chloride, dinitrogen tetroxide, antimony trichloride, hydrogen fluoride, inorganic acids, and pure sulfuric acid. These types of solvents are commonly used in industry for reactions that require a special environment or don't occur in aqueous solutions, and they are also used in chemical research. [15]

Oils and fats are esters that contain three fatty acid units joined to glycerol, a trihydroxy alcohol:

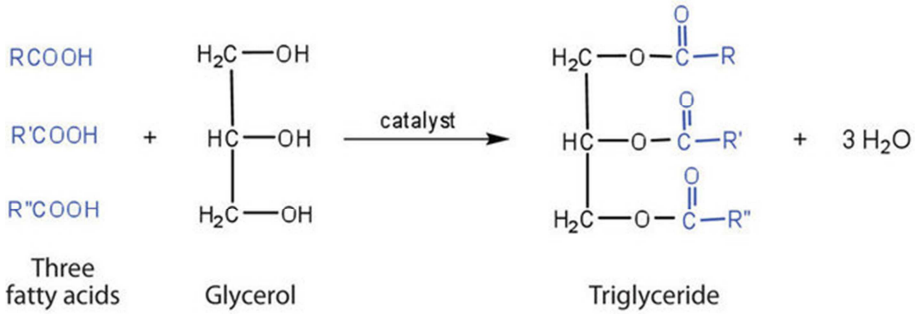


Figure 3. *Chemical structure for oils and fats.*

They are classified into mixed and simple triglyceride. In a simple triglyceride, all three OH groups on the glycerol molecule are esterified with the same fatty acid. In a mixed triglyceride, different fatty acids are used to esterify the three OH groups on the glycerol. Triglycerides obtained from animal sources are commonly solids, while those from plant origin are generally oils. Naturally occurring oils and fats are highly complex mixtures of triglycerides containing many different fatty acids. A triglyceride is oil if it's liquid at room temperature and is fat if it's solid at room temperature. The fatty acid composition of some fats and oils are listed table 1. Oils and fats are poor conductors of heat and electricity, and they serve as good insulators. [33] Most oils are flammable. [34]

Table 1. *The average fatty acid composition of some common fats and oils (%).*

Fats	Lauric	Myristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Butter (Cow)	3	11	27	12	29	2	1
Tallow		3	24	19	43	3	1
Lard		2	26	14	44	10	
Oils	Lauric	Myristic	Palmitic	Stearic	Oleic	Linoleic	Linolenic
Canola Oil			4	2	62	22	10
Coconut Oil	47	18	9	3	6	2	
Corn Oil			11	2	28	58	1
Olive Oil			13	3	71	10	1
Peanut Oil			11	2	48	32	
Soybean Oil			11	4	24	54	7

Totals less than 100% indicates the presence of fatty acids with fewer than 12 carbon atoms or more than 18 carbon atoms

2. Experimental

Possible chemical compounds meeting all criteria are listed in table 1.

Carbon tetra chloride, CCl_4 is an incombustible colorless liquid, used as pesticide, as a cleaning fluid and degreasing agent, in fire extinguishers, and in spot removers. It was used in the past in refrigeration fluid. These uses are banned, and it is only used in some industrial applications because of its harmful effects. [16-18]

Chloroform, $CHCl_3$ is a colorless and dense liquid that is used as a common solvent 1, sedative, anxiolytic, euphoriant, and a powerful anesthetic. [19-21]

Elemental bromine, Br_2 doesn't occur free in nature, as it is a very reactive element. It does exist as mineral salts that is colorless, and water soluble. Commercially sold elemental bromine is produced by its extraction from evaporation ponds in the US, Israel, and China. [22]

Bromine is used as insecticides, agricultural chemicals, dyestuffs, pharmaceuticals, and chemical intermediates. It can be used as flame retardants, they are added to plastic casings for textiles, furniture foams and electronics to make them less flammable. Bromine isn't currently used as flame retardant in the US due to its toxicity. [23-25].

Mercury is the only known metallic liquid element at standard conditions. It occurs naturally as mercuric sulfide (cinnabar). Mercury is used in, barometers, manometers, float valves, mercury switches, mercury relays, fluorescent lamps and other devices. Their use in thermometers and sphygmomanometers has been limited due to its toxicity. [26] It is currently used electrical switches, rectifiers, and in the chemical industry as catalysts. [23].

Sulfuric acid is odorless, colorless, and viscos liquid miscible in water. Pure sulfuric acid is hygroscopic as it has high affinity to water vapor, and it doesn't exist naturally on earth. [27] Concentrated sulfuric acid is an oxidant, has dehydrating properties, and it's highly corrosive to rocks and metals. It causes burns upon contact with body. Dilute sulfuric has no dehydrating or oxidative properties and is less hazard than concentrated sulfuric acid [28, 29] Sulfuric acid is used in the manufacturer of fertilizers in the chemical industry. [30] It's used in wastewater processing, chemical synthesis, mineral processing, oil refining, and in domestic acidic drain cleaners. It can be obtained by dissolving sulfur trioxide in water. [31, 32]

Table 2. *Chemical name, molecular formula and molecular weight of possible chemical compounds meeting the description provided.*

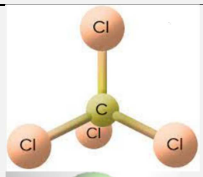
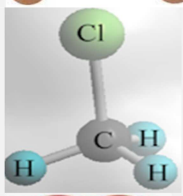
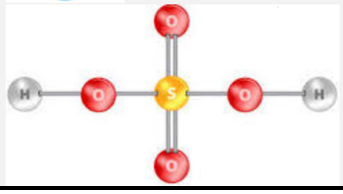
Possible Chemicals	Chemical structure	Molecular Formula	Molecular Weight (g/mol)	Boiling Point	Flash Point
Tetra-chloromethane.		CCl_4	153.8	170.1 °F/ 76.8°C	Not combustible
Methane tri-chloride		$CHCl_3$	119.37	142.07 °F/ 61.15°C	Not combustible
Bromine		Br_2	159.81	(58.8°C, 137.8 °F)	Not Combustible.
Mercury		Hg	200.592	356.73°C / 674.11°F	Not Combustible.
100% Sulfuric Acid		100% conc H_2SO_4	98.079	638.6°F (337°C)	Not Combustible.

Table 1 lists the Chemical name, molecular formula and molecular weight of possible chemical compounds meeting the description provided.

3. Results and Discussion

Bromine, chloroform, carbon tetrachloride, and mercury don't meet the criteria: Elemental bromine is a halogen, the third lightest halogen, while chloroform and carbon tetrachloride are halogenated compound. Mercury is a good conductor of electricity. Carbon tetra chloride, chloroform, and bromine are incombustible liquid at ambient conditions, they are halogens/ hydrogenated compounds, and their boiling points are 76.8°C, 61.15°C, and 58.8°C, below 80°C. Mercury is an incombustible liquid at ambient conditions, it isn't a hydrogenated compound, and its boiling points is greater than 80°C, 356.73°C.

Concentrated sulfuric acid is the only chemical compound that meet the criteria, being non- halogenated, non-combustible, is a liquid or in liquid-vapor equilibrium at ambient conditions, have a normal boiling point of 337°C, a boiling point greater than, ≥80°C, and isn't electrically conductive. It's highly corrosive, it has strong dehydrating properties, and it causes burns upon contact with body. Dilute sulfuric on the other hand, is less hazard than concentrated sulfuric acid, and it has no oxidative or dehydrating properties, but it doesn't meet the criteria as it's a strong electrolyte, and a good conductor of electricity.

Possible classes of compounds might fit the criteria: amino acid solutions, sugar solutions, oils and fats, and non-aqueous inorganic solvents. Amino acids are electrically conductive compounds and don't meet the criteria. Examples of amino acids are Cystine, Phenyl Alanine, Glycine, Proline, and Valine. Sugar solutions, oils and fats, and non-aqueous inorganic solvents are not electrically conductive. Fats are solid at room temperature and don't meet the criteria. Oils are mostly flammable liquids at room temperatures. Silicone oil is an example of oils, and it's a good insulator and a combustible liquid at room temperature, and it doesn't meet the criteria. [34]

Most sugars exist as combustible solids, and their solutions aren't combustible, glucose, fructose are some examples. Maltose is a di saccharide that is a non-combustible liquid solution. [13]. 70% Sorbitol, Glucose, and D- Fructose solutions are compounds that meet the criteria. [35-37]

Inorganic compounds, ionic salts, aren't combustible as they don't react with oxygen, but their solutions are good electrical conductors. They exist as solids at ambient temperatures or as solutions. Examples for inorganic salts are sodium silicate [38, 39], and sodium hypochlorite. [40]. Inorganic salts don't meet the criteria as they are solids, and their solutions are electrical conductors.

Some non-aqueous inorganic solvent such as sulfuryl chloride fluoride, liquid ammonia, liquid sulfur dioxide, bromine pentafluoride, sulfuryl chloride and phosphoryl chloride, dinitrogen tetroxide, antimony trichloride, hydrogen

fluoride are incombustible liquids at ambient temperatures. Sulfuryl chloride fluoride, bromine pentafluoride, sulfuryl chloride and phosphoryl chloride, antimony trichloride, and hydrogen fluoride, don't meet the criteria as they contain halogen atoms, atoms of group seven elements, and they are halogenated compounds.

Inorganic solvents such as hydrogen peroxide (>60% SOLUTION IN WATER), is a non-combustible liquid with negligible electrical conductivity, its electrical conductivity is same as that of water. Its boiling point is Boiling point: 125°C, greater than 80°C, and it meets the criteria. [41]

Liquid ammonia is a non-halogenated fluid and doesn't meet the criteria as it's a flammable liquid with boiling points is below 80°C, -33°C at 1 atm pressure, it's electrically conductive fluid. [42, 43] Liquid sulfur dioxide is a non-halogenated fluid with boiling point below 80°C, with boiling point of -10°C, and it doesn't meet the criteria. [44] Liquid dinitrogen tetroxide is a non- combustible and a non-halogenated fluid with boiling point below 80°C, with boiling point of 21.7°C, and it doesn't meet the criteria. [45, 46]

Some synthetic based oils are non-combustible liquids at ambient conditions such as polyalphaolefin (PAO). They are used in automotive and industrial lubricants, and they are synthetic hydrocarbons that are less volatile than other comparable fluids. [47] Their boiling points are greater than 300°C. [48-50] This class of compounds does meet the criteria as they are liquids at ambient temperatures, and they are non-conductive materials.

4. Conclusion

Most compounds are found to be either highly flammable, combustible, and /or electrically conductive, and only few compounds were found to meet the criteria of being non-halogenated, non-combustible, liquids or in liquid-vapor equilibrium at ambient conditions, having a normal boiling point of ≥80°C, and aren't electrically conductive. These compounds are concentrated 100% sulfuric acid, hydrogen peroxide, sorbitol solution, glucose solution, d- Fructose solution, sucrose solution, polyalphaolefin (PAO), and maltose solutions.

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