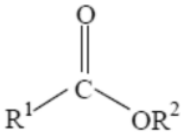
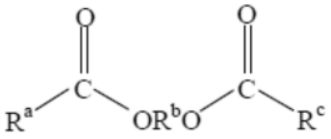
CLAIMS

1. A nonaqueous electrolyte solution for a lithium battery, which solution comprises i) a liquid electrolyte medium; ii) a lithium-containing salt; and iii) at least one oxygen-containing brominated flame retardant selected from

a) a brominated monoester selected from one or more of 2-bromoethyl acetate, 4-bromobutyl acetate, 2-bromovinyl acetate, 3-bromoallyl acetate, 3-bromoallyl butyrate, 2,3-dibromoprop-2-en-1-yl acetate, 2,3-dibromoprop-2-en-1-yl propanoate, (3,5-dibromophenyl)methyl acetate, 3-bromo-2,2-bis(bromomethyl)propyl acetate, methyl 3-bromo-2- propenoate, methyl 2-bromo-acrylate, 2,3-dibromoprop-2-en-1-yl bromoacetate, or (3,5-dibromophenyl)methyl bromoacetate; and



b) a brominated diester which has at least six carbon atoms and at least one bromine atom, and is represented by the formula



wherein

R^a, R^b, and R^c each have at least one carbon atom, and at least one of R^a, R^b, and R^c has at least one bromine atom.

2. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is

I) a) a brominated monoester which has four to twelve carbon atoms and/or one to eight bromine atoms; or

b) a brominated diester which has six to about twenty carbon atoms and/or one to eight bromine atoms; or

a brominated diester which has about six to eighteen carbon atoms and/or one to six bromine atoms.

3. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is

I) a) a brominated diester in which R^b has at least one bromine atom and/or R^a and R^c are the same; or

II) a) a brominated diester in which at least one bromine atom is present in each of R^a, R^b, and R^c.

4. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is

a) a brominated diester in which R^b does not contain quaternary carbon atoms.

5. A solution as in any of Claims 1-2 or 3 wherein two to four carbon atoms of R^b form a bridge between the two ester moieties in the brominated diester.

6. A solution as in any of Claims 1-2, 3, or 5 wherein the brominated diester is 2,3-dibromobut-2-ene-1,4-diyl diacetate, 2,3-dibromobut-2-ene-1,4-diyl bis(2-methylpropanoate),2,3-dibromobut-2-ene-1,4-diyl bis(2-bromobutanoate), 2,2-bis(bromomethyl)-1,3-propanediyl diacetate, or 2,2-bis(bromomethyl)propane-1,3-diyl bis(bromoacetate).

7. A solution as in any of Claims 1-2, 3, or 4-6 wherein the oxygen-containing brominated flame retardant is in an amount of 9.5 wt% or more bromine relative to the total weight of the solution.

8. A solution as in any of Claims 1-2, 3, or 4-7 wherein the liquid electrolyte medium is ethylene carbonate, ethyl methyl carbonate, or a mixture thereof, and/or wherein the lithiumcontaining salt is lithium hexafluorophosphate, lithium di(fluoro)(oxalato)borate, or lithium bis(oxalato)borate.

9. A solution as in any of Claims 1-2, 3, or 4-8 further comprising at least one electrochemical additive selected from:

I) a) unsaturated cyclic carbonates containing three to six carbon atoms,

b) fluorine-containing saturated cyclic carbonates containing three to five carbon atoms and one to four fluorine atoms,

c) tris(trihydrocarbylsilyl) phosphites containing three to nine carbon atoms,

d) trihydrocarbyl phosphates containing three to twelve carbon atoms,

e) cyclic sultones containing three to eight carbon atoms,

f) saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and containing two to six carbon atoms,

g) saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to six carbon atoms,

h) cyclic dioxadithio polyoxide compounds having a 6-membered, 7-membered, or 8-membered ring and containing two to six carbon atoms,

i) another lithium-containing salt, and

j) mixtures of any two or more of the foregoing; or

II) a) unsaturated cyclic carbonates containing three to four carbon atoms,

b) fluorine-containing saturated cyclic carbonates containing three to four carbon atoms and one to two fluorine atoms,

c) tris(trihydrocarbylsilyl) phosphites containing three to six carbon atoms,

d) trihydrocarbyl phosphates containing three to nine carbon atoms,

e) cyclic sultones containing three to four carbon atoms,

f) saturated cyclic hydrocarbyl sulfites having a 5-membered ring and containing two to four carbon atoms,

g) saturated cyclic hydrocarbyl sulfates having a 5-membered ring and containing two to four carbon atoms,

h) cyclic dioxadithio polyoxide compounds having a 6-membered or 7-membered ring and containing two to four carbon atoms,

i) another lithium-containing salt, and

j) mixtures of any two or more of the foregoing.

10. A solution as in Claim 9 wherein the electrochemical additive is selected from:

a) an unsaturated cyclic carbonate in an amount of 0.5 wt% to 12 wt%, relative to the total weight of the nonaqueous electrolyte solution,

b) a fluorine-containing saturated cyclic carbonate in an amount of 0.5 wt% to 8 wt%, relative to the total weight of the nonaqueous electrolyte solution,

c) a tris(trihydrocarbylsilyl) phosphite in an amount of 0.1 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,

d) a trihydrocarbyl phosphate in an amount of 0.5 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,

e) a cyclic sultone in an amount of 0.25 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,

f) a saturated cyclic hydrocarbyl sulfite in an amount of 0.5 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,

g) a saturated cyclic hydrocarbyl sulfate in an amount of 0.25 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,

h) a cyclic dioxadithio polyoxide compound in an amount of 0.5 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution,

i) another lithium-containing salt in an amount of 0.5 wt% to 5 wt%, relative to the total weight of the nonaqueous electrolyte solution, and

j) mixtures of any two or more of the foregoing.

11. A solution as in any of Claims 9 or 10 wherein each electrochemical additive is not used with other electrochemical additives.

12. A solution as in any of Claims 1-2, 3, 4-7, 9 or 10 wherein the solution further comprises a nitrile compound, optionally wherein the nitrile compound is succinonitrile; or wherein the solution further comprises a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

13. A nonaqueous electrolyte solution for a lithium battery as in Claim 1, in which the at least one oxygen-containing brominated flame retardant is selected from the group consisting of methyl bromoacetate, 2-bromoethyl acetate, 4-bromobutyl acetate, 2-bromovinyl acetate, 3-bromoallyl acetate, 3-bromoallyl butyrate, 2,3-dibromoprop-2-en-1-yl acetate, 2,3-dibromoprop-2-en-1-yl propanoate, (3,5-dibromophenyl)methyl acetate, 3-bromo-2,2-bis(bromomethyl)propyl acetate, methyl 3-bromo-2-propenoate, methyl 2-bromo-acrylate, 2,3-dibromoprop-2-en-1-yl bromoacetate, 2,3-dibromoprop-2-en-1-yl 2-methylpropanoate, (3,5-dibromophenyl)methyl bromoacetate, 2,3-dibromobut-2-ene-1,4-diyl diacetate, 2,3-dibromobut-2-ene-1,4-diyl bis(2-methylpropanoate), 2,3-dibromobut-2-ene-1,4-diyl bis(2-bromobutanoate), 2,2-bis(bromomethyl)-1,3-propanediyl diacetate, and 2,2-bis(bromomethyl)propane-1,3-diyl bis(bromoacetate).

14. A solution as in Claim 13 wherein the oxygen-containing brominated flame retardant is in an amount of 9.5 wt% or more bromine relative to the total weight of the solution.

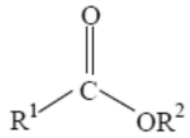
15. A solution as in any of Claims 13 -14 wherein the liquid electrolyte medium is ethylene carbonate, ethyl methyl carbonate, or a mixture thereof, and/or wherein the lithium-containing salt is lithium hexafluorophosphate, lithium di(fluoro)(oxalato)borate, or lithium bis(oxalato)borate.

16. A solution as in any of Claims 13 -15 wherein the solution further comprises a nitrile compound, optionally wherein the nitrile compound is succinonitrile; or a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

17. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 1-2, 3, 4-9, 10 -12, or 13 - 16.

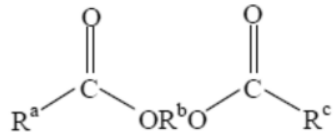
18. A process for producing a nonaqueous electrolyte solution for a lithium battery, which process comprises combining components comprising i) a liquid electrolyte medium; ii) a lithium containing salt; and iii) at least one oxygen-containing brominated flame retardant selected from

a) a brominated monoester selected from one or more of 2-bromoethyl acetate, 4-bromobutyl acetate, 2-bromovinyl acetate, 3-bromoallyl acetate, 3-bromoallyl butyrate, 2,3-dibromoprop-2-en-1-yl acetate, 2,3-dibromoprop-2-en-1-yl propanoate, (3,5-dibromophenyl)methyl acetate, 3-bromo-2,2-bis(bromomethyl)propyl acetate, methyl 3-bromo-2- propenoate, methyl 2-bromo-acrylate, 2,3-dibromoprop-2-en-1-yl bromoacetate, or (3,5-dibromophenyl)methyl bromoacetate;



and

b) a brominated diester which has at least six carbon atoms and at least one bromine atom, and is represented by the formula



wherein

Ra, Rb, and Rc each have at least one carbon atom, and at least one of R^a, R^b, and R^c has at least one bromine atom.

19. A process as in Claim 18 wherein the components further comprise at least one electrochemical additive selected from:

a) unsaturated cyclic carbonates containing three to six carbon atoms,

b) fluorine-containing saturated cyclic carbonates containing three to five carbon atoms and one to four fluorine atoms,

c) tris(trihydrocarbylsilyl) phosphites containing three to nine carbon atoms,

d) trihydrocarbyl phosphates containing three to twelve carbon atoms,

e) cyclic sultones containing three to eight carbon atoms,

f) saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and

containing two to six carbon atoms,

g) saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to six carbon atoms,

h) cyclic dioxadithio polyoxide compounds having a 6-membered, 7-membered, or 8-membered ring and containing two to six carbon atoms,

i) another lithium-containing salt, and

j) mixtures of any two or more of the foregoing.

20. A process for producing a nonaqueous electrolyte solution for a lithium battery as in Claim 18, in which the at least one oxygen-containing brominated flame retardant is selected from the group consisting of methyl bromoacetate, 2,3-dibromoprop-2-en-1-yl 2-methylpropanoate, (3,5-dibromophenyl)methyl bromoacetate, 2,3-dibromobut-2-ene-1,4-diyl diacetate, 2,3-dibromobut-2-ene-1,4-diyl bis(2-methylpropanoate), 2,3-dibromobut-2-ene-1,4-diyl bis(2-bromobutanoate), 2,2-bis(bromomethyl)-1,3-propanediyl diacetate, and 2,2-bis(bromomethyl)propane-1,3-diyl bis(bromoacetate).

21. A process as in Claim 20 wherein the components further comprise at least one electrochemical additive selected from vinylene carbonate, 4-fluoro-ethylene carbonate, tris(trimethylsilyl)phosphite, triallyl phosphate, 1,3-propane sultone, 1,3-propene sultone, ethylene sulfite, 1,3,2-dioxathiolane 2,2-dioxide, 1,5,2,4-dioxadithiane 2,2,4,4-tetroxide, lithium di(fluoro)(oxalato)borate, lithium bis(oxalato)borate, and mixtures of any two or more of these.

22. Each of the following molecules separately, as a new composition of matter:

2,3-dibromoprop-2-en-1-yl propanoate;

2,3-dibromoprop-2-en-1-yl 2-methylpropanoate;

2,3-dibromoprop-2-en-1-yl bromoacetate;

2,3-dibromobut-2-ene-1,4-diyl bis(2-methylpropanoate);

2,3-dibromobut-2-ene-1,4-diyl bis(2-bromobutanoate).