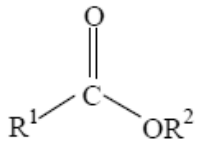
THAT WHICH IS CLAIMED IS:

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

α) which has three carbon atoms and at least one bromine atom, or

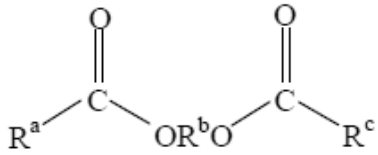
β) which has at least four carbon atoms and at least one bromine atom, and is represented by the formula



wherein

R^1 and R^2 each have at least one carbon atom, and at least one of R^1 and R^2 has at least one bromine atom, with the proviso that when R^2 is a benzyl group and there is at least one bromine atom in the benzyl group, R^1 is a branched or straight chain alkyl group; 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 about twelve carbon atoms and/or one to about eight bromine atoms; or

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

II) a) a brominated monoester in which R^1 has at least one bromine atom and one to about eight carbon atoms; or

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

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

~~a) a brominated monoester in which R1 has at least one bromine atom and one to about eight carbon atoms; or~~

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

~~4~~ 3. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is

I) a) a brominated monoester in which R^2 has at least one bromine atom and two to about eight carbon atoms; or

b) 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 monoester in which R^1 and R^2 each have at least one bromine atom, R^1 has one to about eight carbon atoms, and R^2 has one to about nine carbon atoms; or

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

~~5. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is~~

~~a) a brominated monoester in which R^1 and R^2 each have at least one bromine atom, R^1 has one to about eight carbon atoms, and R^2 has one to about nine carbon atoms; or~~

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

~~6~~ 4. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is

a) a brominated monoester in which R^2 does not contain quaternary carbon atoms; or

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

~~7~~ 5. A solution as in any of Claims 1-2 ~~1-3~~ wherein the brominated monoester is 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.

~~8~~ 6. A solution as in any of Claims 1-2 or 3 ~~1-5~~ wherein two to about four carbon atoms of R^b form a bridge between the two ester moieties in the brominated diester.

~~9~~ 7. A solution as in any of Claims 1-2, 3, ~~1-5~~ or ~~8~~ 6 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).

~~10~~ 8. A solution as in any of Claims 1-2, 3, or 4-7 ~~1-9~~ wherein the oxygen-containing brominated flame retardant is in an amount of about 9.5 wt% or more bromine relative to the total weight of the solution.

~~11~~ 9. A solution as in any of Claims 1-2, 3, or 4-8 ~~1-10~~ 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.

~~12~~ 10. A solution as in any of Claims 1-2, 3, or 4-9 ~~1-11~~ further comprising at least one electrochemical additive selected from:

I)

a) unsaturated cyclic carbonates containing three to about six carbon atoms,
b) fluorine-containing saturated cyclic carbonates containing three to about five carbon atoms and one to about four fluorine atoms,
c) tris(trihydrocarbylsilyl) phosphites containing three to about nine carbon atoms,
d) trihydrocarbyl phosphates containing three to about twelve carbon atoms,
e) cyclic sultones containing three to about eight carbon atoms,
f) saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
g) saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to about six carbon atoms,

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

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

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

d) trihydrocarbyl phosphates containing three to about nine carbon atoms,

e) cyclic sultones containing three to about four carbon atoms,

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

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

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

i) another lithium-containing salt, and

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

~~13. A solution as in Claim 12 wherein the electrochemical additive is selected from:~~

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

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

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

~~d) trihydrocarbyl phosphates containing three to about nine carbon atoms,~~

~~e) cyclic sultones containing three to about four carbon atoms,~~

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

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

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

~~i) another lithium-containing salt, and~~

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

~~14~~ 11. A solution as in Claim ~~12~~ 10 ~~or 13~~ wherein the electrochemical additive is selected from:

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

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

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

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

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

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

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

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

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

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

~~15~~ 12. A solution as in any of Claims 10 or 11 ~~12-14~~ wherein each electrochemical additive is not used with other electrochemical additives.

~~16~~ 13. A solution as in any of Claims 1-2, 3, 4-8, 10 or 11 ~~1-14~~ 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.

~~17. A solution as in Claim 15 wherein the nitrile compound is succinonitrile.~~

~~18. A solution as in any of Claims 1-14 wherein the solution further comprises a nitrile compound and another lithium-containing salt.~~

~~19. A solution Claim 18 wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.~~

~~20. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 1-19.~~

~~21~~ 14. A nonaqueous electrolyte solution for a lithium battery as in Claim 1, in which the ~~solution comprises~~

~~i)~~ ~~a liquid electrolyte medium;~~

~~ii)~~ ~~a lithium-containing salt; and~~

~~iii)~~ 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).

~~22~~ 15. A solution as in Claim ~~21~~ 14 wherein the oxygen-containing brominated flame retardant is in an amount of about 9.5 wt% or more bromine relative to the total weight of the solution.

~~23~~ 16. A solution as in any of Claims ~~21-22~~ 14-15 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.

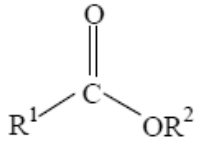
~~24~~ 17. A solution as in any of Claims ~~21-23~~ 14-16 wherein the solution further comprises a nitrile compound, optionally wherein the nitrile compound is succinonitrile; or a nitrile compound and another lithium-containing salt, optionally wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.

~~25. A solution as in Claim 24 wherein the nitrile compound is succinonitrile or wherein the nitrile compound is succinonitrile and the lithium-containing salt is lithium di(fluoro)(oxalato)borate.~~

~~26~~ 18. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 1-2, 3, 4-10, 11-13, or 14-17 ~~21-25~~.

~~27~~ 19. 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

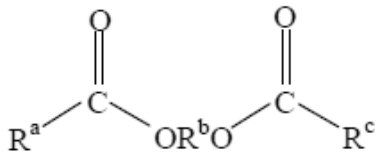
a) a brominated monoester
   α) which has three carbon atoms and at least one bromine atom, or
   β) which has at least four carbon atoms and at least one bromine atom, and is represented by the formula



wherein

R^1 and R^2 each have at least one carbon atom, and at least one of R^1 and R^2 has at least one bromine atom, with the proviso that when R^2 is a benzyl group and there is at least one bromine atom in the benzyl group, R^1 is a branched or straight chain alkyl group; 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.

~~28~~ 20. A process as in Claim ~~27~~ 19 wherein the components further comprise at least one electrochemical additive selected from:

a) unsaturated cyclic carbonates containing three to about six carbon atoms,
b) fluorine-containing saturated cyclic carbonates containing three to about five carbon atoms and one to about four fluorine atoms,
c) tris(trihydrocarbylsilyl) phosphites containing three to about nine carbon atoms,
d) trihydrocarbyl phosphates containing three to about twelve carbon atoms,
e) cyclic sultones containing three to about eight carbon atoms,
f) saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
g) saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
h) cyclic dioxadithio polyoxide compounds having a 6-membered, 7-membered, or 8-membered ring and containing two to about six carbon atoms,
i) another lithium-containing salt, and
j) mixtures of any two or more of the foregoing.

~~29~~ 21. A process for producing a nonaqueous electrolyte solution for a lithium battery as in Claim 19, in which the ~~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 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).

~~30~~ 22. A process as in Claim ~~29~~ 21 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.

~~31~~ 23. 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)~~;~~

~~2,2-bis(bromomethyl)propane-1,3-diyl bis(bromoacetate)~~.