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 benzene comprising one phenyl ring having two or three bromine atoms bound to the phenyl ring and at least one oxygen-containing group bound to the phenyl ring via an oxygen atom, any remaining sites on the phenyl ring each being bound to a hydrogen atom, with the proviso that when there is only one oxygen-containing group, the oxygen-containing group is a methoxy group or an ethoxy group, and

B) a brominated fluorobenzene comprising one phenyl ring having at least one bromine atom bound to the phenyl ring, at least one fluorine atom bound to the phenyl ring, and an oxygen-containing group bound to the phenyl ring via an oxygen atom, wherein the oxygen-containing group is a methoxy group or an ethoxy group.

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

a brominated benzene which has ~~about~~ eight to about twenty carbon atoms, two to about ten oxygen atoms, and/or a bromine content of about 30 wt% or more relative to the total weight of the brominated flame retardant; or

a brominated fluorobenzene having one fluorine atom bound to the phenyl ring, one bromine atom or two bromine atoms bound to the phenyl ring, and/or a bromine content of about 35 wt% or more relative to the total weight of the brominated flame retardant.

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

I) a brominated benzene which has two oxygen-containing groups on the phenyl ring, which oxygen-containing groups are the methoxy or ethoxy group and a hydrocarbyloxy group; or

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a brominated fluorobenzene in which a bromine atom is adjacent to the oxygen-containing group; or

II) a brominated benzene which has one oxygen-containing group bound to the phenyl ring; or a brominated fluorobenzene which has only one fluorine atom bound to the phenyl ring, and the fluorine atom is *para* relative to the oxygen-containing group.

4. A nonaqueous electrolyte solution as in any of Claims 1-3 wherein the brominated fluorobenzene is 2,6-dibromo-4-fluoro-1-[(2-methoxy)ethoxy]benzene, 2,6-dibromo-4-fluoro-1-methoxybenzene, 2,6-dibromo-4-fluoro-1-ethoxybenzene, or 4-fluoro-2-bromo-1-methoxybenzene.

5. A nonaqueous electrolyte solution as in Claim 3 wherein

in I) the oxygen-containing brominated flame retardant is a brominated benzene which is 2,4-dibromo-5-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,4-dibromo-5-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,5-dibromo-4-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,5-dibromo-4-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 4,5-dibromo-2-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 3,4,5-tribromo-1-ethoxy-2-(1,4,7,10-tetraoxaundecyl)-benzene, 2,4-dibromo-5-methoxy-1-[(2-ethoxy)ethoxy]benzene, or 2,4-dibromo-5-ethoxy-1-[(2-ethoxy)ethoxy]benzene;

in II) the oxygen-containing brominated flame retardant is a brominated benzene which has at least one bromine atom is adjacent to the oxygen-containing group, optionally wherein the brominated benzene is 2,4-dibromo-1-[(2-ethoxy)ethoxy]benzene, 2,6-dibromo-1-[(2-ethoxy)ethoxy]benzene, or 2,6-dibromo-4-fluoro-1-[(2-methoxy)ethoxy]benzene.

6. A nonaqueous electrolyte solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is a brominated benzene which has three bromine atoms on the phenyl ring, and which has three oxygen-containing groups on the phenyl ring, wherein i) one of the oxygen-containing groups is an alkoxyether group and the other two oxygen-containing groups are hydrocarbyloxy groups, or ii) all three oxygen-containing groups are alkoxyether groups, optionally wherein the brominated benzene is 2,6-dimethoxy-1-(1,4,7,10-tetraoxaundecyl)-3,4,5-tribromobenzene or 4,5,6-tribromo-1,2,3-tri(2-methoxyethoxy)benzene.

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7. A nonaqueous electrolyte solution as in any of Claims 1-3, 5, or 6 wherein the oxygen-containing brominated flame retardant is a brominated benzene, and wherein each alkoxyether group has two to ~~about~~ ten carbon atoms and two to eight oxygen atoms, and/or wherein the oxygen-containing brominated flame retardant is a brominated benzene which is in an amount of 12.5 wt% or more bromine relative to the total weight of the solution.

8. A nonaqueous electrolyte solution as in any of Claims 1-3 or 4 wherein the oxygen-containing brominated flame retardant is a brominated fluorobenzene which is in an amount of about 11.5 wt% or more bromine relative to the total weight of the solution.

9. A nonaqueous electrolyte solution as in any of Claims 1-3, 4-5, 6, 7, or 8 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.

10. A nonaqueous electrolyte solution as in any of Claims 1-3, 4-5, 6, 7, or 8-9 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 ~~about~~ 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 about 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.

11. A nonaqueous electrolyte solution as in Claim 10 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 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 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,

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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.

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

13. A nonaqueous electrolyte solution as in any of Claims 1-3, 4-5, 6, 7, 8-10, or 11 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.

14. 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 2,6-dimethoxy-1-(1,4,7,10-tetraoxaundecyl)-3,4,5-tribromobenzene, 4,5,6-tribromo-1,2,3-tri(2-methoxyethoxy)benzene, 2,4-dibromo-5-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,4-dibromo-5-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,5-dibromo-4-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,5-dibromo-4-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 4,5-dibromo-2-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 3,4,5-tribromo-2-(1,4,7,10-tetraoxaundecyl)-1-ethoxybenzene, 2,4-dibromo-5-methoxy-1-[(2-ethoxy)ethoxy]benzene, 2,4-dibromo-5-ethoxy-1-[(2-ethoxy)ethoxy]benzene, 2,4-dibromo-1-[(2-ethoxy)ethoxy]benzene, 2,6-dibromo-1-[(2-ethoxy)ethoxy]benzene, 2,6-dibromo-4-fluoro-1-[(2-methoxy)ethoxy]benzene, 2,6-dibromo-4-fluoro-1-methoxybenzene, 2,6-dibromo-4-fluoro-1-ethoxybenzene, and 4-fluoro-2-bromo-1-methoxybenzene.

15. A nonaqueous electrolyte solution as in Claim 14 wherein the oxygen-containing brominated flame retardant is in an amount of about 12 wt% or more bromine relative to the total weight of the solution.

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16. A nonaqueous electrolyte solution as in Claim 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.

17. A nonaqueous electrolyte solution as in any of Claims 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.

18. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 1-3, 4-5, 6, 7, 8-10, 11-13, or

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 benzene comprising one phenyl ring having two or three bromine atoms bound to the phenyl ring and at least one oxygen-containing group bound to the phenyl ring via an oxygen atom, any remaining sites on the phenyl ring each being bound to a hydrogen atom, with the proviso that and when there is only one oxygen-containing group, the oxygen-containing group is a methoxy group or an ethoxy group, and
    B) a brominated fluorobenzene comprising a phenyl ring having at least one bromine atom bound to the phenyl ring, at least one fluorine atom bound to the phenyl ring, and an oxygen-containing group bound to the phenyl ring via an oxygen atom, wherein the oxygen-containing group is a methoxy group or an ethoxy group.

20. A process as in Claim 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,

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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.

21. A process as in any of Claims 19-20 wherein the components further comprise 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.

22. A process for producing a nonaqueous electrolyte solution for a lithium battery as in Claim 19, in which the at least one oxygen-containing brominated flame retardant is selected from the group consisting of 2,6-dimethoxy-1-(1,4,7,10-tetraoxaundecyl)-3,4,5-tribromobenzene, 4,5,6-tribromo-1,2,3-tri(2-methoxyethoxy)benzene, 2,4-dibromo-5-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,4-dibromo-5-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,5-dibromo-4-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 2,5-dibromo-4-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 4,5-dibromo-2-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene, 3,4,5-tribromo-1-ethoxy-2-(1,4,7,10-tetraoxaundecyl)-benzene, 2,4-dibromo-5-methoxy-1-[(2-ethoxy)ethoxy]benzene, 2,4-dibromo-5-ethoxy-1-[(2-ethoxy)ethoxy]benzene, 2,4-dibromo-1-[(2-ethoxy)ethoxy]benzene, 2,6-dibromo-1-[(2-ethoxy)ethoxy]benzene, 2,6-dibromo-4-fluoro-1-[(2-methoxy)ethoxy]benzene, 2,6-dibromo-4-fluoro-1-methoxybenzene, 2,6-dibromo-4-fluoro-1-ethoxybenzene, and 4-fluoro-2-bromo-1-methoxybenzene.

23. A process as in Claim 22 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; and/or

a nitrile compound, optionally wherein the nitrile compound is succinonitrile, or wherein the components further comprise 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.

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

2,4-Dibromo-5-methoxy-1-(1,4,7,10-tetraoxaundecyl)benzene;

2,5-Dibromo-4-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene;

4,5-Dibromo-2-ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene;

3,4,5-Tribromo-2-(1,4,7,10-tetraoxaundecyl)-1-ethoxybenzene;

2,4-Dibromo-5-methoxy-1-[(2-ethoxy)ethoxy]benzene;

2,6-Dibromo-4-fluoro-1-[(2-methoxy)ethoxy]benzene;

3,4,5-Tribromo-1-ethoxy-2-(1,4,7,10-tetraoxaundecyl)-benzene;

2-Ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene;

4-Ethoxy-1-(1,4,7,10-tetraoxaundecyl)benzene;

2,6-Dimethoxy-1-(1,4,7,10-tetraoxaundecyl)-3,4,5-tribromobenzene;

4,5,6-Tribromo-1,2,3-tri(2-methoxyethoxy)benzene.

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