

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 noncyclic ether,
 - b) a brominated cyclic diether,
 - c) a brominated noncyclic carbonate having two hydrocarbyl groups in which at least one hydrocarbyl group has at least one unsaturated carbon-carbon bond, or has aromatic character, and
 - d) a brominated cyclic carbonate having a carbonate ring, which carbonate ring has at least one unsaturated carbon-carbon bond.
2. A solution as in Claim 1 wherein the brominated flame retardant has a boiling point of about 95°C or higher.
3. A solution as in Claim 1 wherein the brominated flame retardant has a boiling point in the range of about 75°C to about 450°C.
4. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant has about three to about ten carbon atoms, one to about five bromine atoms, and/or a bromine content of about 35 wt% or more relative to the total weight of the oxygen-containing brominated flame retardant.
5. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is a brominated cyclic diether or a brominated cyclic carbonate which has a 5-membered or 6-membered ring, and optionally has about three to about ten carbon atoms, one to about five bromine atoms, and/or a bromine content of about 35 wt% or more relative to the total weight of the oxygen-containing brominated flame retardant.
6. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is a brominated noncyclic ether which has about three to about ten carbon atoms and a bromine content of about 30 wt% or more relative to the total weight of the oxygen-containing brominated flame retardant;

a brominated cyclic diether which has about three to about eight carbon atoms and one to about three bromine atoms;
a brominated noncyclic carbonate which has about four to about eight carbon atoms and one to about four bromine atoms; or
a brominated cyclic carbonate which has about three to about ten carbon atoms, one to about five bromine atoms, and a bromine content of about 40 wt% or more relative to the total weight of the oxygen-containing brominated flame retardant.

7. A solution as in any of Claims 1, 4, or 6 wherein the oxygen-containing brominated flame retardant is

a brominated cyclic diether containing two or more bromine atoms wherein all of the bromine atoms are in one or more hydrocarbyl groups, or all of the bromine atoms are bound to carbon atoms of the ring;
a brominated noncyclic carbonate which has at least one alkyl, alkenyl, aryl, or ar-alkyl group; or
a brominated cyclic carbonate containing two or more bromine atoms wherein all of the bromine atoms are in one or more hydrocarbyl groups bound to the carbonate ring, or all of the bromine atoms are bound to carbon atoms of the carbonate ring.

8. A solution as in Claim 7 wherein the oxygen-containing brominated flame retardant is

a brominated cyclic diether containing two or more bromine atoms and having two or more hydrocarbyl groups bound to the carbonate ring, and wherein the bromine atoms are in different hydrocarbyl groups;
a brominated noncyclic carbonate having hydrocarbyl groups which are selected from methyl, ethyl, propenyl, and phenyl groups; or
a brominated cyclic carbonate containing two or more bromine atoms and having two or more hydrocarbyl groups bound to the carbonate ring, wherein the bromine atoms are in different hydrocarbyl groups.

9. A solution as in any of Claims 1-5 wherein the oxygen-containing brominated flame retardant is

a brominated cyclic diether having two or more hydrocarbyl groups bound to the carbonate ring, which hydrocarbyl groups are methyl groups; or

a brominated cyclic carbonate having two or more hydrocarbyl groups bound to the carbonate ring, which hydrocarbyl groups are methyl groups.

10. A solution of Claim 1 or 8 wherein the oxygen-containing brominated flame retardant is a brominated noncyclic carbonate in which one hydrocarbyl group is a methyl group.

11. A solution as in Claim 1 wherein the oxygen-containing brominated flame retardant is 2,4-dibromophenyl methyl carbonate or 2,3-dibromo-2-propenyl methyl carbonate.

12. A solution as in any of Claims 1-11 wherein the oxygen-containing brominated flame retardant is in an amount of about 10 wt% or more bromine relative to the total weight of the solution.

13. A solution as in any of Claims 1-12 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)(oxolato)borate, or lithium bis(oxolato)borate.

14. A solution as in any of Claims 1-13 further comprising 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.

15. A solution as in Claim 14 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.
16. A solution as in Claim 14 or 15 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.

17. A solution as in any of Claims 14-16 wherein the electrochemical additive is a saturated cyclic hydrocarbyl sulfate, a cyclic sultone, a tris(trihydrocarbylsilyl) phosphite, or another lithium-containing salt.

18. A solution as in Claim 14 wherein the electrochemical additive is a saturated cyclic hydrocarbyl sulfate in an amount of about 1 wt% to about 4 wt%, a cyclic sultone in an amount of about 0.5 wt% to about 4 wt%, a tris(trihydrocarbylsilyl) phosphite in an amount of about 0.15 wt% to about 1 wt%, or another lithium-containing salt in an amount of about 1 wt% to about 4 wt%, each relative to the total weight of the nonaqueous electrolyte solution.

19. A solution as in Claim 14 or 18 wherein the electrochemical additive is 1,3,2-dioxathiolane 2,2-dioxide, 1-propene-1,3-sultone, 1-propane-1,3-sultone, tris(trimethylsilyl)phosphite, or lithium bis(oxolato)borate.

20. A solution as in Claim 18 or 19 wherein each electrochemical additive is not used with other electrochemical additives.

21. A solution as in any of Claims 14-16 wherein the electrochemical additive is selected from vinylene carbonate, 4-fluoro-ethylene carbonate, tris(trimethylsilyl)phosphite, triallyl phosphate, 1-propane-1,3-sultone, 1-propene-1,3-sultone, ethylene sulfite, 1,3,2-dioxathiolane 2,2-dioxide, 1,5,2,4-dioxadithiane 2,2,4,4-tetroxide, lithium di(fluoro)(oxolato)borate, lithium bis(oxolato)borate, and mixtures of any two or more of these.

22. A solution as in Claim 21 wherein the electrochemical additive is selected from:
vinylene carbonate in an amount of about 0.5 wt% to about 3 wt%, relative to the total weight of the nonaqueous electrolyte solution;
vinylene carbonate in an amount of about 8 wt% to about 11 wt%, relative to the total weight of the nonaqueous electrolyte solution;
4-fluoro-ethylene carbonate in an amount of about 1.5 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution;

tris(trimethylsilyl)phosphite in an amount of about 0.2 wt% to about 3 wt%, relative to the total weight of the nonaqueous electrolyte solution;

triallyl phosphate in an amount of about 1 wt% to about 5 wt%, relative to the total weight of the nonaqueous electrolyte solution;

1-propane-1,3-sultone or 1-propene-1,3-sultone in an amount of about 0.5 wt% to about 4 wt%, relative to the total weight of the nonaqueous electrolyte solution;

1,3,2-dioxathiolane, 2-oxide in an amount of about 1 wt% to about 4 wt%, relative to the total weight of the nonaqueous electrolyte solution;

1,3,2-dioxathiolane 2,2-dioxide in an amount of about 1 wt% to about 4 wt%, relative to the total weight of the nonaqueous electrolyte solution;

1,5,2,4-dioxadithiane 2,2,4,4-tetroxide in an amount of about 1 wt% to about 4 wt%, relative to the total weight of the nonaqueous electrolyte solution;

lithium bis(oxolato)borate in an amount of about 1 wt% to about 4 wt%, relative to the total weight of the nonaqueous electrolyte solution; and

mixtures of any two or more of these.

23. A solution as in Claim 21 or 22 wherein the electrochemical additive is selected from 1-propane-1,3-sultone, 1-propene-1,3-sultone, 1,3,2-dioxathiolane 2,2-dioxide, tris(trimethylsilyl)phosphite, and lithium bis(oxolato)borate.

24. A solution as in Claim 21 wherein the electrochemical additive selected from 1-propane-1,3-sultone in an amount of about 0.5 wt% to about 4 wt%, 1-propene-1,3-sultone in an amount of about 0.5 wt% to about 4 wt%, 1,3,2-dioxathiolane 2,2-dioxide, in an amount of about 1 wt% to about 4 wt%, and lithium bis(oxolato)borate in an amount of about 1 wt% to about 4 wt%, each relative to the total weight of the nonaqueous electrolyte solution.

25. A solution as in Claim 23 or 24 wherein each electrochemical additive is not used with other electrochemical additives.

26. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 1-25.

27. A nonaqueous electrolyte solution for a lithium battery, which solution comprises

- a liquid electrolyte medium;
- a lithium-containing salt; and

iii) at least one oxygen-containing brominated flame retardant selected from the group consisting of 1-bromo-2-methoxyethane, 1-bromo-3-methoxypropane, 2-bromo-1,1-dimethoxyethane, 2-bromo-1,4-dimethoxybenzene, 1-bromo-2-(methoxymethoxy)ethane, 1-bromovinyl ethyl ether, 1,2-dibromo-3-methoxy-1-propene, 1,2-dibromo-3-ethoxy-1-propene, di(ethylene glycol) dibromovinyl ether, 4-bromo-1,3-dioxolane, 2-bromomethyl-1,3-dioxolane, 2-dibromomethyl-1,3-dioxolane, 2-tribromomethyl-1,3-dioxolane, 2,2-bis(bromomethyl)-1,3-dioxolane, 2-(bromomethyl)-1,4-dioxane, 5,5-bis(bromomethyl)-2-methyl-1,3-dioxane, 5,5-bis(bromomethyl)-2-ethyl-1,3-dioxane, 3-bromo-2-propenyl methyl carbonate, 2,3-dibromo-2-propenyl methyl carbonate, 2,3,3-tribromo-2-propenyl methyl carbonate, 3-bromo-2-propenyl ethyl carbonate, 2,4-dibromophenyl methyl carbonate, bis(2,3-dibromo-2-propenyl) carbonate, 4-bromo-1,3-dioxol-2-one, 4,5-dibromo-1,3-dioxol-2-one, 4-bromomethyl-1,3-dioxol-2-one, 4,4-bis(bromomethyl)-1,3-dioxol-2-one, and 4,5-bis(bromomethyl)-1,3-dioxol-2-one.

28. A solution as in Claim 27 wherein the oxygen-containing brominated flame retardant is selected from the group consisting of 1-bromo-2-methoxyethane, 1-bromo-3-methoxypropane, 2-bromo-1,1-dimethoxyethane, 2-bromo-1,4-dimethoxybenzene, 1-bromo-2-(methoxymethoxy)ethane, 1-bromovinyl ethyl ether, 1,2-dibromo-3-methoxy-1-propene, 1,2-dibromo-3-ethoxy-1-propene, and di(ethylene glycol) dibromovinyl ether.

29. A solution as in Claim 27 wherein the oxygen-containing brominated flame retardant is selected from the group consisting of 4-bromo-1,3-dioxolane, 2-bromomethyl-1,3-dioxolane, 2-dibromomethyl-1,3-dioxolane, 2-tribromomethyl-1,3-dioxolane, 2,2-bis(bromomethyl)-1,3-dioxolane, 2-(bromomethyl)-1,4-dioxane, 5,5-bis(bromomethyl)-2-methyl-1,3-dioxane, and 5,5-bis(bromomethyl)-2-ethyl-1,3-dioxane.

30. A solution as in Claim 27 wherein the oxygen-containing brominated flame retardant is selected from the group consisting of 3-bromo-2-propenyl methyl carbonate, 2,3-dibromo-2-propenyl methyl carbonate, 2,3,3-tribromo-2-propenyl methyl carbonate, 3-bromo-2-propenyl ethyl carbonate, 2,4-dibromophenyl methyl carbonate, and bis(2,3-dibromo-2-propenyl) carbonate.

31. A solution as in Claim 27 wherein the oxygen-containing brominated flame retardant is selected from the group consisting of 4-bromo-1,3-dioxol-2-one, 4,5-dibromo-

1,3-dioxol-2-one, 4-bromomethyl-1,3-dioxol-2-one, 4,4-bis(bromomethyl)-1,3-dioxol-2-one, and 4,5-bis(bromomethyl)-1,3-dioxol-2-one.

32. A solution as in any of Claims 27-30 wherein the oxygen-containing brominated flame retardant is in an amount of about 10 wt% or more bromine relative to the total weight of the solution.

33. A solution as in any of Claims 27-30 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)(oxolato)borate, or lithium bis(oxolato)borate.

34. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 27-33.

35. 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 noncyclic ether,
 - b) a brominated cyclic diether,
 - c) a brominated noncyclic carbonate having two hydrocarbyl groups in which at least one hydrocarbyl group has at least one unsaturated carbon-carbon bond, or has aromatic character, and
 - d) a brominated cyclic carbonate having a carbonate ring, which carbonate ring has at least one unsaturated carbon-carbon bond.

36. A process as in Claim 35 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.

37. 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 the group consisting of 1-bromo-2-methoxyethane, 1-bromo-3-methoxypropane, 2-bromo-1,1-dimethoxyethane, 2-bromo-1,4-dimethoxybenzene, 1-bromo-2-(methoxymethoxy)ethane, 1-bromovinyl ethyl ether, 1,2-dibromo-3-methoxy-1-propene, 1,2-dibromo-3-ethoxy-1-propene, di(ethylene glycol) dibromovinyl ether, 4-bromo-1,3-dioxolane, 2-bromomethyl-1,3-dioxolane, 2-dibromomethyl-1,3-dioxolane, 2-tribromomethyl-1,3-dioxolane, 2,2-bis(bromomethyl)-1,3-dioxolane, 2-(bromomethyl)-1,4-dioxane, 5,5-bis(bromomethyl)-2-methyl-1,3-dioxane, 5,5-bis(bromomethyl)-2-ethyl-1,3-dioxane, 3-bromo-2-propenyl methyl carbonate, 2,3-dibromo-2-propenyl methyl carbonate, 2,3,3-tribromo-2-propenyl methyl carbonate, 3-bromo-2-propenyl ethyl carbonate, 2,4-dibromophenyl methyl carbonate, bis(2,3-dibromo-2-propenyl) carbonate, 4-bromo-1,3-dioxol-2-one, 4,5-dibromo-1,3-dioxol-2-one, 4-bromomethyl-1,3-dioxol-2-one, 4,4-bis(bromomethyl)-1,3-dioxol-2-one, and 4,5-bis(bromomethyl)-1,3-dioxol-2-one.

38. A process as in Claim 37 wherein the components further comprise at least one electrochemical additive selected from vinylene carbonate, 4-fluoro-ethylene carbonate, tris(trimethylsilyl)phosphite, triallyl phosphate, 1-propane-1,3-sultone, 1-propene-1,3-sultone, ethylene sulfite, 1,3,2-dioxathiolane 2,2-dioxide, 1,5,2,4-dioxadithiane 2,2,4,4-tetroxide, lithium di(fluoro)(oxolato)borate, lithium bis(oxolato)borate, and mixtures of any two or more of these.

- 39. 1,2-Dibromo-3-ethoxy-1-propene.
- 40. Di(ethylene glycol) dibromovinyl ether.
- 41. 3-Bromo-2-propenyl methyl carbonate.
- 42. 3-Bromo-2-propenyl ethyl carbonate.
- 43. 2,3-Dibromo-2-propenyl methyl carbonate.
- 44. 2,3,3-Tribromo-2-propenyl methyl carbonate.
- 45. 2,4-Dibromophenyl methyl carbonate.
- 46. 5,5-Bis(bromomethyl)-2-methyl-1,3-dioxane.
- 47. 5,5-Bis(bromomethyl)-2-ethyl-1,3-dioxane.
- 48. 4-Bromo-1,3-dioxolane.