

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 brominated flame retardant, in a flame retardant amount, wherein the brominated flame retardant has a boiling point of about 60°C or higher and has a bromine content of about 55 wt% or more based on the weight of the brominated flame retardant, with the proviso that the brominated flame retardant is not tribromoethylene or tribromoneopentyl alcohol.
2. A solution as in Claim 1 wherein the brominated flame retardant has a boiling point of about 85°C or higher.
3. A solution as in Claim 1 wherein the brominated flame retardant has a boiling point in the range of about 65°C to about 340°C.
4. A solution as in Claim 1 wherein the flame retardant amount is more than 4 wt% relative to the total weight of the solution, and wherein the brominated flame retardant has a boiling point of about 145°C to about 250°C and has a bromine content of about 85 wt% or more based on the weight of the brominated flame retardant.
5. A solution as in Claim 1 wherein the flame retardant amount is more than 6 wt% relative to the total weight of the solution, and wherein the brominated flame retardant has a boiling point of about 150°C to about 225°C and has a bromine content of about 75 wt% or more based on the weight of the brominated flame retardant.
6. A solution as in Claim 1 wherein the flame retardant amount is more than 8 wt% relative to the total weight of the solution, and wherein the brominated flame retardant has a boiling point of about 85°C to about 250°C and has a bromine content of about 65 wt% or more based on the weight of the brominated flame retardant.
7. A solution as in Claim 1 wherein the flame retardant amount is more than 15 wt% relative to the total weight of the solution, and wherein the brominated flame retardant has a bromine content of about 65 wt% or more based on the weight of the brominated flame retardant.

8. A solution as in Claim 1 wherein the brominated flame retardant is a mixture of 1,2-dibromoethane and 2,3-dibromo-2-propen-1-ol.
9. A solution as in Claim 1 which also comprises 2-phenoxy-2,4,4,6,6-pentafluoro-1,3,5,2λ5,4λ5,6λ5triazatriphosphinine, wherein the brominated flame retardant is selected from 1,2-dibromoethane and 1,3-dibromopropane, with the provisos that:
- A) the weight ratio of 1,2-dibromoethane to 2-phenoxy-2,4,4,6,6-pentafluoro-1,3,5,2λ5,4λ5,6λ5triazatriphosphinine is about 1.5:1 to about 3:1 and the flame retardant amount is about 6 wt% or more flame retardant molecules relative to the total weight of the nonaqueous electrolyte solution;
- B) the weight ratio of 1,3-dibromopropane to 2-phenoxy-2,4,4,6,6-pentafluoro-1,3,5,2λ5,4λ5,6λ5triazatriphosphinine is about 1.5:1 to about 3:1, and the flame retardant amount is about 6 wt% or more flame retardant molecules relative to the total weight of the nonaqueous electrolyte solution.
10. A solution as in any of Claims 1-9 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 or lithium bis(oxalato)borate.
11. A solution as in any of Claims 1-10 further comprising at least one electrochemical additive selected from:
- unsaturated cyclic carbonates containing three to about six carbon atoms,
 - fluorine-containing saturated cyclic carbonates containing three to about five carbon atoms and one to about four fluorine atoms,
 - tris(trihydrocarbylsilyl) phosphites containing three to about nine carbon atoms,
 - trihydrocarbyl phosphates containing three to about twelve carbon atoms,
 - cyclic sultones containing three to about eight carbon atoms,
 - saturated cyclic hydrocarbyl sulfites having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
 - saturated cyclic hydrocarbyl sulfates having a 5-membered or 6-membered ring and containing two to about six carbon atoms,
 - cyclic dioxadithio polyoxide compounds having a 6-membered, 7-membered, or 8-membered ring and containing two to about six carbon atoms,
 - another lithium-containing salt, and
 - mixtures of any two or more of the foregoing.

12. A solution as in Claim 11 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.
13. A solution as in Claim 11 or 12 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.

14. A solution as in any of Claims 11-13 wherein the electrochemical additive is a saturated cyclic hydrocarbyl sulfate, a cyclic sultone, a tris(trihydrocarbylsilyl) phosphite, or another lithium-containing salt.

15. A solution as in Claim 11 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 0.2 wt% to about 3 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.

16. A solution as in Claim 11 or 15 wherein the electrochemical additive is 1,3,2-dioxathiolane 2,2-dioxide, 1,3-propene sultone, 1,3-propane sultone, tris(trimethylsilyl)phosphite, or lithium bis(oxalato)borate.

17. A solution as in Claim 15 or 16 wherein each electrochemical additive is not used with other electrochemical additives.

18. A solution as in any of Claims 11-13 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 bis(oxalato)borate, and mixtures of any two or more of these.

19. A solution as in Claim 18 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;

1,3-propane sultone or 1,3-propene 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(oxalato)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.

20. A solution as in Claim 18 or 19 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(oxalato)borate.

21. A solution as in Claim 18 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(oxalato)borate in an amount of about 1 wt% to about 4 wt%, each relative to the total weight of the nonaqueous electrolyte solution.

22. A solution as in Claim 20 or 21 wherein each electrochemical additive is not used with other electrochemical additives.

23. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and the nonaqueous electrolyte solution as in any of Claims 1-22.

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

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

c) at least one brominated flame retardant, in a flame retardant amount, wherein the brominated flame retardant is selected from 1,1,2-tribromoethane, 1,1,2,2-tetrabromoethane, bromochloromethane, tribromomethane, 1,3-dibromopropane, 2,3-dibromo-2-propen-1-ol, dibromomethane, 1,2-dibromoethane, 1,2-dibromoethylene, 1,4-dibromobutane, 1,5-dibromopentane, and 1,3-dibromobenzene.

25. A solution as in Claim 24 wherein the flame retardant amount is more than 4 wt% relative to the total weight of the solution, and wherein the brominated flame retardant is selected from the group consisting of 1,1,2-tribromoethane, 1,1,2,2-tetrabromoethane, and bromoform.

26. A solution as in Claim 24 wherein the flame retardant amount is more than 6 wt% relative to the total weight of the solution, and wherein the brominated flame retardant is 1,3-dibromopropane.

27. A solution as in Claim 24 wherein the flame retardant amount is more than 8 wt% relative to the total weight of the solution, and wherein the brominated flame retardant is selected from the group consisting of 2,3-dibromo-2-propen-1-ol, dibromomethane, 1,2-dibromoethane, 1,2-dibromoethylene, 1,4-dibromobutane, 1,5-dibromopentane, and mixtures of any two or more of the foregoing.

28. A solution as in Claim 24 wherein the flame retardant amount is more than 15 wt% relative to the total weight of the solution, and wherein the brominated flame retardant is 1,3-dibromobenzene.

29. A solution as in Claim 25 wherein the nonaqueous electrolyte solution further comprises vinylene carbonate in an amount of about 8 wt% to about 11 wt%, relative to the total weight of the nonaqueous electrolyte solution.

30. A solution as in any of Claims 24-29 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 or lithium bis(oxalato)borate.

31. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims 24-30.

32. 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 brominated flame retardant, in a flame retardant amount, wherein the brominated flame retardant has a boiling point of about 60°C or higher and has a bromine content of about 55 wt% or more based on the weight of the brominated flame retardant, with the proviso that the brominated flame retardant is not tribromoethylene or tribromoneopentyl alcohol.

33. A process as in Claim 32 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.

34. 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 brominated flame retardant, in a flame retardant amount, wherein the brominated flame retardant is selected from 1,1,2-tribromoethane, 1,1,2,2-tetrabromoethane, bromochloromethane, tribromomethane, 1,3-dibromopropane, 2,3-

dibromo-2-propen-1-ol, dibromomethane, 1,2-dibromoethane, 1,2-dibromoethylene, 1,4-dibromobutane, 1,5-dibromopentane, and 1,3-dibromobenzene.

35. A process as in Claim 34 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 bis(oxalato)borate, and mixtures of any two or more of these.