

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, and wherein
 - a) 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, or
 - b) 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, or
 - c) 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, or
 - d) 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.
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.~~

~~84.~~ 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.

~~95.~~ 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.

~~106.~~ A solution as in any of Claims 1-5 ~~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.

~~117.~~ A solution as in any of Claims 1-6 ~~1-10~~ 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.

~~128.~~ A solution as in Claim ~~11-7~~ 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.

~~139.~~ A solution as in Claim ~~11-7~~ or ~~12-8~~ 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~~10. A solution as in any of Claims ~~11-13~~9 wherein the electrochemical additive is a saturated cyclic hydrocarbyl sulfate, a cyclic sultone, a tris(trihydrocarbysilyl) phosphite, or another lithium-containing salt.

~~15~~11. A solution as in Claim ~~11-7~~ 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(trihydrocarbysilyl) 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~~12. A solution as in Claim ~~11-7~~ or ~~15-11~~ 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~~13. A solution as in Claim ~~15-11~~ or ~~16-12~~ wherein each electrochemical additive is not used with other electrochemical additives.

~~18~~14. A solution as in any of Claims ~~11-13~~9 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~~15. A solution as in Claim ~~18-14~~ 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~~16. A solution as in Claim ~~18-14~~ or ~~19-15~~ 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~~17. A solution as in Claim ~~18-14~~ 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~~18. A solution as in Claim ~~20-16~~ or ~~21-17~~ wherein each electrochemical additive is not used with other electrochemical additives.

~~23~~19. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and the nonaqueous electrolyte solution as in any of Claims ~~1-181-22~~.

~~24~~20. A nonaqueous electrolyte solution for a lithium battery, which solution comprises

a) a liquid electrolyte medium;

- b) 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, with the proviso that when the brominated flame retardant is 2,3-dibromo-2-propen-1-ol, the flame retardant amount is more than 8 wt% relative to the total weight of the solution.

~~25~~21. A solution as in Claim ~~24-20~~ 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~~22. A solution as in Claim ~~24-20~~ 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~~23. A solution as in Claim ~~24-20~~ 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~~24. A solution as in Claim ~~24-20~~ 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~~25. A solution as in Claim ~~25-21~~ 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.

~~3026~~. A solution as in any of Claims ~~2420-29-25~~ 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.

~~3127~~. A nonaqueous lithium battery comprising a positive electrode, a negative electrode, and a nonaqueous electrolyte solution as in any of Claims ~~2420-3026~~.

~~3228~~. 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, and wherein
 - a) 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, or
 - b) 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, or
 - c) 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, or
 - d) 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.

~~33~~29. A process as in Claim ~~32-28~~ 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~~30. 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, with the proviso that when the brominated flame retardant is 2,3-dibromo-2-propen-1-ol, the flame retardant amount is more than 8 wt% relative to the total weight of the solution.

~~35~~31. A process as in Claim ~~34-30~~ 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.