We Claim:

1. A hydrogen carrier fluid composition, comprising:

an electrolyte; and

one of a rich liquid organic hydrogen carrier ("LOHC") component and a lean LOHC component; wherein

the rich liquid organic hydrogen carrier component includes:

a first rich LOHC, defined by at least one cyclohexyl-based compound; and

a second rich LOHC, defined by one or more C_{4-12} alkyl alcohol; and

the lean LOHC component includes:

a first lean LOHC, defined by at least one cyclohexyl-based compound having at least one unsaturated bond, and

a second lean LOHC, defined by a C_{4-7} alkyl ketone, a C_{4-6} lactone, or a mixture thereof.

2. The composition as claimed in claim 1;
wherein:
the one of a rich LOHC component and a lean LOHC component is the rich LOHC component.

3. The composition as claimed in claim 2, wherein the electrolyte component comprises an alkali metal salt, an alkaline earth metal salt, an ammonium salt, Ce-alkyl-Ce-aryl sulfonic acid or a mixture thereof.

4. The composition as claimed in claim 3;
wherein:
a counter ion of the alkali metal salt, the alkaline earth metal salt, the ammonium salt is hydroxide anion, perchlorate anion, borate anion, carbonate anion or acetate anion.

5. The composition as claimed in any one of claims 1 to 4, wherein the electrolyte component includes water.

6. The composition as claimed in any one of claims 2 to 5;

wherein:

each one of the at least one cyclohexyl-based compound has at least one heteroatom;

each one of the at least one heteroatom, independently, is one of nitrogen, oxygen, and sulphur.

7. The composition as claimed in any one of claims 2 to 5;

wherein

each one of the at least one cyclohexyl-based compound is substituted with one or more of OH, a C1-C6 alkyl group, and a C1-C6 alkyl group functionalized with one or more alcohol groups.

8. The composition as claimed in claim 2 to 5;

wherein:

the cyclohexyl-based compound is substituted with a cyclohexyl or a 5- or 6-membered N-heterocycle group.

9. The composition as claimed in any one of claims 2 to 5;

wherein:

the cyclohexyl-based compound is a monocyclic compound or a fused ring compound;

each one of the monocyclic compound and the fused rings compound, independently, is optionally substituted with one or more OH groups, one or more alkyl groups, and one or more OH groups and one or more alkyl groups.

10. The composition as claimed in claim 9;

wherein:

the fused ring cyclohexyl-based compound has at least two fused cyclohexyl rings, or a cycloalkyl ring and a 5- or 6-membered heterocycle having at least one heteroatom.

11. The composition as claimed in claim 10;

wherein:

each one of the at least one heteroatom, independently, is one of nitrogen, oxygen, and sulphur.

12. The composition as claimed in any one of claims 2 to 5;
wherein:
the first rich LOHC includes cyclohexane, methylcyclohexane, cyclohexanol, cyclohexanediol, or any combination thereof; and
the second rich LOHC includes butanol, pentanediol, or any combination thereof, and the lactone is delta-valerolactone.

13. The composition as claimed in any one of claims 2 to 12;
wherein:
the composition includes:
about 40wt%-90wt% of the first rich LOHC;
about 20wt%-60wt% of the second rich LOHC; and
about 1wt%-20wt% of the electrolyte.

14. The composition as claimed in any one of claims 2 to 13;
further comprising a transition metal complex or a post transition metal complex.

15. The composition as claimed in any one of claims 2 to 14;
further comprising an organic redox mediator.

16. The composition as claimed in any one of claims 2 to 15;
wherein:
the composition is disposed in a liquid state under ambient conditions.

17. A method of producing gaseous diatomic hydrogen, comprising:
electrochemically dehydrogenating the rich LOHC as claimed in any one of claims 2 to 16, with effect that gaseous diatomic hydrogen is produced; and
recovering the produced gaseous diatomic hydrogen.

18. The composition as claimed in claim 1;
wherein:
the one of a rich LOHC component and a lean LOHC component is the lean LOHC component.

19. The composition as claimed in claim 18;
wherein:
the electrolyte component comprises an alkali metal salt, an alkaline earth metal salt, an ammonium salt, Ce- alkyl- Ce- aryl sulfonic acid or a mixture thereof.

20. The composition as claimed in claim 19;
wherein:
a counter ion of the alkali metal salt, the alkaline earth metal salt, the ammonium salt is hydroxide anion, perchlorate anion, borate anion, carbonate anion or acetate anion.

21. The composition as claimed in any one of claims 18 to 20;
wherein:
the electrolyte component includes water.

22. The composition as claimed in any one of claims 18 to 21;
wherein:
each one of the at least one cyclohexyl-based compound, having at least one unsaturated bond, has at least one heteroatom;
each one of the at least one heteroatom, independently, is one of nitrogen, oxygen, and sulphur.

23. The composition as claimed in any one of claims 18 to 21;
wherein
each one of the at least one cyclohexyl-based compound, having at least one unsaturated bond, is substituted with one or more of OH, a C1-C6 alkyl group, and a C1-C6 alkyl group functionalized with one or more alcohol groups.

24. The composition as claimed in claim 18 to 21;
wherein:
the cyclohexyl-based compound, having at least one unsaturated bond, is substituted with a cyclohexyl or a 5- or 6-membered N-heterocycle group.

25. The composition as claimed in any one of claims 18 to 21;
wherein:

the cyclohexyl-based compound, having at least one unsaturated bond, is a monocyclic compound or a fused rings compound;
each one of the monocyclic compound and the fused rings compound, independently, is optionally substituted with one or more OH groups, one or more alkyl groups, and one or more OH groups and one or more alkyl groups.

26. The composition as claimed in claim 25;
wherein:
the fused rings cyclohexyl-based compound has at least two fused cyclohexyl rings, or a cycloalkyl ring and a 5- or 6-membered heterocycle having at least one heteroatom.

27. The composition as claimed in claim 26;
wherein:
each one of the at least one heteroatom, independently, is one of nitrogen, oxygen, and sulphur,

28. The composition as claimed in any one of claims 18 to 21;
wherein:
the first lean LOHC includes a cyclohexene, a methyl cyclohexene, a cyclohexenol, a cyclohexanone, phenol, or any combination thereof; and
the second lean LOHC includes butanone, pentanedione, benzoquinone, cyclohexanedione, or any combination thereof.

29. The composition as claimed in any one of claims 18 to 28;
wherein:
the composition includes:
up to about 90wt% of the lean LOHC;
about 20wt%-60wt% of the second lean LOHC; and
about 1wt%-20wt% of the electrolyte.

30. The composition as claimed in any one of claims 18 to 29;
further comprising a transition metal complex or a post transition metal complex.

31. The composition as claimed in any one of claims 18 to 30;

further comprising an organic redox mediator.

32. The composition as claimed in any one of claims 18 to 31;
wherein:
the composition is disposed in a liquid state under ambient conditions.

33. A method of producing gaseous diatomic hydrogen, comprising:
electrochemically hydrogenating the lean LOHC component as claimed in any one of claims 18 to 32.