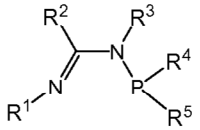
CLAIMS

What is claimed:

1. An N^2-phosphinyl amidine compound characterized by having the formula:



wherein:

R^1 is a C_1 to C_{30} organyl group,

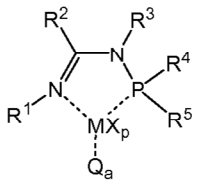
R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups,

R^3 is hydrogen, a C_1 to C_{30} organyl group ,or a C_1 to C_{30} organyl group consisting essentially of inert functional groups, and

R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups.

2. A method of preparing an N^2-phosphinyl amidine compound according to claim 1, comprising:
   a) contacting a metal amide with a nitrile under conditions capable of forming a metal amidinate; and
   b) contacting a phosphine halide with the metal amidinate under conditions capable of forming a compound comprising an N^2-phosphinyl amidine group.

3. A metal salt complex of an N^2-phosphinyl amidine compound according to claim 1, characterized by having the formula:



wherein:

R^1 is a C_1 to C_{30} organyl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups

R^3 is hydrogen or a C_1 to C_{30} organyl group consisting essentially of inert functional groups,

R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups,

MX_p represents the metal salt where M is a transition metal, X is a monoanion, and p ranges from 2 to 6,

Q is a neutral ligand, and

a ranges from 0 to 6.

4. A method of preparing an N^2-phosphinyl amidine metal salt complex according to claim 3 comprising:
   a) contacting a transition metal salt with an N^2-phosphinyl amidine compound according to claim 1; and
   b) forming the N^2-phosphinyl amidine metal salt complex.

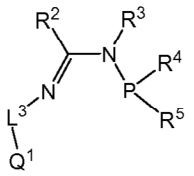
5. A catalyst system comprising: an N^2-phosphinyl amidine metal salt complex according to claim 3 and a metal alkyl.

6. A method of preparing a catalyst system according to claim 5, comprising forming a catalyst system mixture comprising: the N^2-phosphinyl amidine metal salt complex according to claim 3; and the metal alkyl.

7. An olefin oligomerization process comprising:
   a) contacting an olefin and the catalyst system according to claim 5, wherein the metal alkyl is an aluminoxane; and
   b) forming an olefin oligomer product.

8. An olefin oligomerization process comprising:
   a) forming a catalyst system mixture according to claim 6, wherein the metal alkyl is an aluminoxane;
   b) contacting the catalyst system mixture with an olefin; and
   c) forming an olefin oligomer product.

9. The subject matter of any of claim 1-8, wherein R^1 comprises a metal complexing group and a linking group linking the metal complexing group to the N^1 nitrogen atom of an N^2-phosphinyl amidine group of the N^2-phosphinyl amidine compound characterized by having the formula



wherein Q^1 represents the metal complexing group and is a dialkyl aminyl group, a dicycloalkyl aminyl group, a di(substituted cycloalkyl) aminyl group, an N-(alkyl)-N-(cycloalkyl) aminyl group, an N-(alkyl)-N-(substituted cycloalkyl) aminyl group, an N-(cycloalkyl)-N-(substituted cycloalkyl) aminyl group, a diaryl aminyl group, a di(substituted aryl) aminyl group, an N-aryl-N-(substituted aryl) aminyl group, an N-alkyl-N-aryl aminyl group, an N-alkyl-N-(substituted aryl) aminyl group, a dialkyl phosphinyl group, a dicycloalkyl phosphinyl group, a di(substituted cycloalkyl) phosphinyl group), an N-(alkyl)-N-(cycloalkyl) phosphinyl group, an N-(alkyl)-N-(substituted cycloalkyl) phosphinyl group, an N-(cycloalkyl)-N-(substituted cycloalkyl) phosphinyl group, a diaryl phosphinyl group, a di(substituted aryl) phosphinyl group, a P-aryl-P-(substituted aryl) phosphinyl group, a P-alkyl-P-aryl phosphinyl group, a P-alkyl-P-(substituted aryl) phosphinyl group, an alkyl etheryl group, an aryl etheryl group, a substituted aryl etheryl group, an alkyl sulfidyl group, an aryl sulfidyl group, a substituted aryl sulfidyl group, a furanyl group, a substituted furanyl group, a thienyl group, a substituted thienyl group, a tetrahydrofuranyl group, a substituted tetrahydrofuranyl group, a thiophanyl group, a substituted thiophanyl group, a pyridinyl group, a substituted pyridinyl group, a morphilinyl group, a substituted morphilinyl group, a pyranyl group, a substituted pyranyl group, a tetrahydropyranyl group, a substituted tetrahydropyranyl group, a quinolinyl group, a substituted quinolinyl group, a pyrrolyl group, a substituted pyrrolyl group, a pyrrolidinyl group, a substituted pyrrolidinyl group, a piperidinyl group, or a substituted piperidinyl group, and L^3 represents the linking group and is a bond or a C_1 to C_{10} organyl group.

10. The subject matter of any of claims 1-8, wherein R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group.

11. The subject matter of any of claims 1-8, wherein R^1 is a phenyl group or a substituted phenyl group.

12. The subject matter of any of claims 1-8, wherein R^1 is a phenyl group, a 2-substituted phenyl group, a 4-substituted phenyl group, a 2,4-disubstituted phenyl group, a 2,6-disubstituted phenyl group, a 3,5-disubstituted phenyl group, or a 2,4,6-trisubstituted phenyl group.

13. The subject matter of claim 11 or 12, wherein each substituent of the substituted phenyl group is independently a halide, a C_1 to C_5 alkyl group, or a C_1 to C_5 alkoxy group.

14. The subject matter of any of claims 1-8, wherein R^1 is a phenyl group, a 2-methylphenyl group, a 2-ethylphenyl group, a 2-isopropyl group, a 2-tert-butylphenyl group, a 4-methylphenyl group, a 4-ethylphenyl group, a 4-isopropyl group, a 4-tert-butylphenyl group, a 2,6-dimethylphenyl group, a 2,6-diethylphenyl group, a 2,6-diisopropylphenyl group, a 2-methyl-6-isopropylphenyl group, a 3,5-dimethylphenyl group, a 2,4,6-trimethylphenyl group, or a 2,6-dimethyl-4-tert-butylphenyl group.

15. The subject matter of any preceding claim, wherein R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_3 to C_{15} aliphatic heterocyclic group, a C_3 to C_{15} substituted aliphatic heterocyclic group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, a C_7 to C_{20} substituted aralkyl group, a C_3 to C_{20} heteroaryl group, or a C_3 to C_{20} substituted heteroaryl group.

16. The subject matter of any preceding claim, wherein R^2 is a C_6 to C_{20} phenyl group or a C_6 to C_{20} substituted phenyl group.

17. The subject matter of any of claims 1-14, wherein R^2 is a C_6 to C_{20} benzyl group, a C_6 to C_{20} substituted benzyl group, a C_6 to C_{20} ethylphenyl group, or a C_6 to C_{20} substituted ethylphenyl group.

18. The subject matter of any preceding claim, wherein R^3 is hydrogen, a C_1 to C_{10} alkyl group, a C_1 to C_{15} cycloalkyl group, a C_1 to C_{15} substituted cycloalkyl group, a C_3 to C_{15} aliphatic heterocyclic group, a C_3 to C_{15} substituted aliphatic heterocyclic group, a C_6 to C_{15} aryl group, a C_6 to C_{15} substituted aryl group, a C_3 to C_{15} heteroaryl group, or a substituted C_3 to C_{15} heteroaryl group.

19. The subject matter of any of claims 1-17, wherein R^3 is hydrogen.

20. The subject matter of any preceding claim, wherein R^4 and R^5 are independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_3 to C_{15} aliphatic heterocyclic group, a C_3 to C_{15} substituted aliphatic heterocyclic group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_3 to C_{20} heteroaryl group, or a C_3 to C_{20} substituted heteroaryl group.

21. The subject matter of any preceding claim, wherein R^4 and R^5 are independently a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, or a neopentyl group.

22. The subject matter of any of claims 1-19, wherein R^4 and R^5 are each independently a cyclopentyl group, a substituted cyclopentyl group, a cyclohexyl group, or a substituted cyclohexyl group.

23. The subject matter of any of claims 1-19, wherein R^4 and R^5 are independently a phenyl group or a substituted phenyl group.

24. The subject matter of any of claims 1-19, wherein R^4 and R^5 are independently a phenyl group, a 2-substituted phenyl group, a 4-substituted phenyl group, a 2,4-disubstituted phenyl group, a 2,6-disubstituted phenyl group, a 3,5-disubstituted phenyl group, or a 2,4,6-trisubstituted phenyl group.

25. The subject matter of any of claims 1-8, wherein
R^1 is a phenyl group or a substituted phenyl group,
R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, or a C_7 to C_{20} substituted aralkyl group,
R^3 is hydrogen, and
R^4 and R^5 are independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group.

26. The method of claim 2, wherein the metal amidinate of step a) is neutralized with a protic compound to form a non-metal amidine compound.

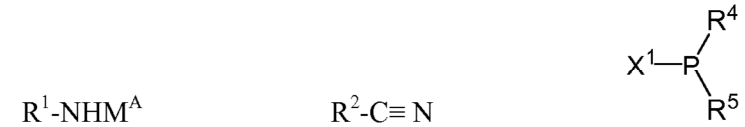
27. The method of claim 26, wherein the non-metal amidine compound is isolated and optionally purified and then contacted with a metal alkyl compound to form the metal amidinate under conditions capable of forming the amidinate.

28. The method of claim 2, wherein the metal amidinate of step a) is contacted with the phosphine halide without forming a non-metal amidine compound.

29. The method of claim 2, wherein the compound comprising the N^2-phosphinyl amidine group is isolated and optionally purified.

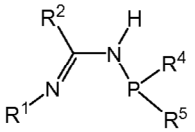
30. The method of claim 2, wherein the metal amide is formed by contacting an amine and a Group 1 or Group 2 metal alkyl.

31. The method of claim 2, wherein the metal amide has Structure MA1, the nitrile has Structure N1, the phosphine halide has the Structure PH1,



Structure MA1 **Structure N1** **Structure PH1**

and the compound comprising an N^2-phosphinyl amidine group is characterized by having the formula:



wherein

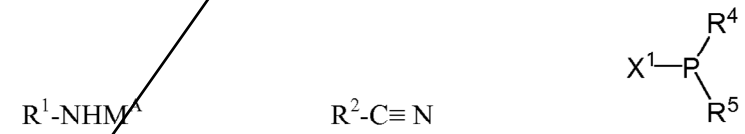
M^A is a Group 1 or Group 2 metal,

R^1 is a C_1 to C_{30} organyl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups, and

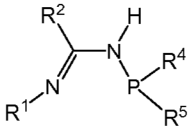
R^4 and R^5 are independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups.

32. The method of claim 2, wherein the metal amide has Structure MA1, the nitrile has Structure N1, the phosphine halide has the Structure PH1,



Structure MA1 **Structure N1** **Structure PH1**

and the compound comprising an N^2-phosphinyl amidine group is characterized by having the formula:



wherein

M^A is a Group 1 or Group 2 metal,

R^1 is a phenyl group or a substituted phenyl group,

R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, or a C_7 to C_{20} substituted aralkyl group,

R^3 is hydrogen, and

R^4 and R^5 are each independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group.

33. The subject matter of any of claims 3-8, wherein the metal salt comprises a Group 3-10 transition metal.

34. The subject matter of any of claims 3-8, wherein the metal of the metal salt is in a +2 or +3 oxidation state.

35. The subject matter of any of claims 3-8, wherein the metal salt comprises chromium.

36. The subject matter of any of claims 3-8, wherein the metal salt is a chromium(III) carboxylate, a chromium(III) β-diketonate, or a chromium(III) halide.

37. The subject matter of any of claims 3-8, wherein the metal salt is a chromium(III) chloride.

38. The method of claim 4, wherein the transition metal salt and the N^2-phosphinyl amidine compound are contacted at a transition metal salt to N^2-phosphinyl amidine compound equivalent ratio of at least 0.9:1.

39. The method of claim 4, wherein the transition metal salt and the N^2-phosphinyl amidine compound are contacted in a solvent.

40. The subject matter of any of claims 5-8, wherein the metal alkyl comprises an aluminoxane and the aluminoxane comprises methylaluminoxane (MAO), modified methylaluminoxane (MMAO), ethylaluminoxane, n-propylaluminoxane, iso-propylaluminoxane, n-butylaluminoxane, sec-butylaluminoxane, iso-butylaluminoxane, t-butyl aluminoxane, 1-pentylaluminoxane, 2-pentylaluminoxane, 3-pentylaluminoxane, iso-pentylaluminoxane, neopentylaluminoxane, or mixtures thereof.

41. The subject matter of claim 40, wherein the aluminoxane comprises modified methylaluminoxane (MMAO).

42. The subject matter of claim 40, wherein the aluminum of the aluminoxane to the metal of the metal complex molar ratio is at least 5:1.

43. The method of claim 6 or 8, wherein the mixture further comprises a solvent.

44. The method of claim 6, wherein the metal alkyl is an aluminoxane and the aluminoxane is thermally aged at a temperature of from 30 °C to 100 °C for at least 12 hours before contacting it with the metal complex.

45. The method of claim 6 or 8, wherein the catalyst system mixture is aged in the substantial absence of an olefin for at least 15 minutes.

46. The process of claim 8, wherein the catalyst system mixture further comprises a first solvent.

47. The process of claim 46, wherein the first solvent is a C_6-C_{20} aromatic hydrocarbon, a C_1-C_{10} halogenated hydrocarbon, or a combination thereof.

48. The process of claim 46, wherein the first solvent is benzene, toluene, ethylbenzene, xylene, mesitylene, hexamethylbenzene, or any combination thereof.

49. The process of claim 46, wherein the catalyst system mixture and olefin are contacted in a second solvent.

50. The process of claim 49, wherein the second solvent is a C_2-C_{20} aliphatic hydrocarbon, a C_6-C_{20} aromatic hydrocarbon, or a combination thereof.

51. The process of claim 49, wherein the second solvent is cyclohexane, a substituted cyclohexane, or a combination thereof.

52. The process of claim 7 or 8, wherein the olefin oligomer is formed at reaction conditions capable of forming an olefin oligomer comprising a temperature ranging from 20 °C to 150 °C.

53. The process of claim 7 or 8, wherein the olefin comprises ethylene.

54. The process of claim 53, wherein the ethylene partial pressure at which the olefin oligomer is formed is at least 50 psig.

55. The process of claim 7 or 8, wherein the olefin consists essentially of ethylene and a liquid product comprises at least 70 wt. % C_6 and C_8 olefins.

56. The process of claim 55, wherein the C_6 olefin product comprises at least 90 wt. % 1-hexene.

57. The process of claim 56, wherein the C_8 olefin product comprises at least 90 wt. % 1-octene.

57. The process of claim 8, wherein catalyst system mixture is contacted with an olefin and hydrogen and the hydrogen partial pressure is at least 5 psig.

58. The process of claim 7 or 8, wherein

R^1 is a phenyl group or a substituted phenyl group,

R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, or a C_7 to C_{20} substituted aralkyl group,

R^3 is hydrogen,

R^4 and R^5 are independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

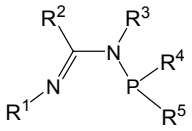
MX_p comprises a chromium(III) halide,

Q is a THF, and

a ranges from 0 to 6.

CLAIMS

1. An N^2-phosphinyl amidine compound characterized by having the formula:



wherein:

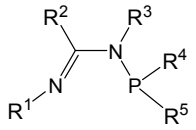
R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

R^3 is hydrogen, and

R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof.

2. A method of preparing the N^2-phosphinyl amidine compound according to claim 1, characterized by having the formula:



wherein:

R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

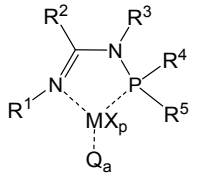
R^3 is hydrogen, and

R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof, comprising:

a) contacting a metal amide with a nitrile under conditions capable of forming a metal amidinate; and

b) contacting a phosphine halide with the metal amidinate under conditions capable of forming a compound comprising an N^2-phosphinyl amidine group.

3. A metal salt complex of the N^2-phosphinyl amidine compound according to claim 1, characterized by having the formula:



wherein:

R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

R^3 is hydrogen,

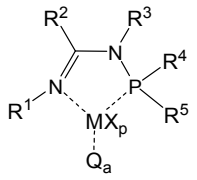
R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

MX_p represents the metal salt where M is a transition metal, X is a monoanion, and p ranges from 2 to 6,

Q is a neutral ligand, and

a ranges from 0 to 6.

4. A method of preparing the N^2-phosphinyl amidine metal salt complex according to claim 3, characterized by having the formula:



wherein:

R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

R^3 is hydrogen,

R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting

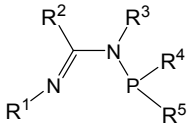
of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

MX_p represents the metal salt where M is a transition metal, X is a monoanion, and p ranges from 2 to 6,

Q is a neutral ligand, and

a ranges from 0 to 6, comprising:

a) contacting a transition metal salt with an N^2-phosphinyl amidine compound, characterized by having the formula:



wherein:

R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof,

R^3 is hydrogen, and

R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof; and

b) forming the N^2-phosphinyl amidine metal salt complex.

5. The N^2-phosphinyl amidine compound of claim 1, wherein R^1 is a phenyl group or a substituted phenyl group.

6. The N^2-phosphinyl amidine compound of claim 1, wherein R^1 is a phenyl group, a 2-substituted phenyl group, a 4-substituted phenyl group, a 2,4-disubstituted phenyl group, a 2,6-disubstituted phenyl group, a 3,5-disubstituted phenyl group, or a 2,4,6-trisubstituted phenyl group.

7. The N^2-phosphinyl amidine compound of claim 1, wherein each substituent of the substituted phenyl group of R^1 is independently a halide, a C_1 to C_5 alkyl group, or a C_1 to C_5 alkoxy group.

8. The N^2-phosphinyl amidine compound of claim 1, wherein R^1 is a phenyl group, a 2-methylphenyl group, a 2-ethylphenyl group, a 2-isopropylphenyl group, a 2-tert-butylphenyl group, a 4-methylphenyl group, a 4-ethylphenyl group, a 4-isopropylphenyl group, a 4-tert-butylphenyl group, a 2,6-dimethylphenyl group, a 2,6-diethylphenyl group, a 2,6-diisopropylphenyl group, a 2-methyl-6-isopropylphenyl group, a 3,5-dimethylphenyl group, a 2,4,6-trimethylphenyl group, or a 2,6-dimethyl-4-tert-butylphenyl group.

9. The N^2-phosphinyl amidine compound of claim 1, wherein R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_3 to C_{15} aliphatic heterocyclic group, a C_3 to C_{15} substituted aliphatic heterocyclic group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, a C_7 to C_{20} substituted aralkyl group, a C_3 to C_{20} heteroaryl group, or a C_3 to C_{20} substituted heteroaryl group.

10. The N^2-phosphinyl amidine compound of claim 1, wherein R^2 is a phenyl group or a C_6 to C_{20} substituted phenyl group.

11. The N^2-phosphinyl amidine compound of claim 1, wherein R^2 is a benzyl group, a C_6 to C_{20} substituted benzyl group, an ethylphenyl group, or a C_6 to C_{20} substituted ethylphenyl group.

12. The N^2-phosphinyl amidine compound of claim 1, wherein R^4 and R^5 are independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_3 to C_{15} aliphatic heterocyclic group, a C_3 to C_{15} substituted aliphatic heterocyclic group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_3 to C_{20} heteroaryl group, or a C_3 to C_{20} substituted heteroaryl group.

13. The N^2-phosphinyl amidine compound of claim 1, wherein R^4 and R^5 are independently a methyl group, an ethyl group, an isopropyl group, a tert-butyl group, or a neopentyl group.

14. The N^2-phosphinyl amidine compound of claim 1, wherein R^4 and R^5 are each independently a cyclopentyl group, a substituted cyclopentyl group, a cyclohexyl group, or a substituted cyclohexyl group.

15. The N^2-phosphinyl amidine compound of claim 1, wherein R^4 and R^5 are independently a phenyl group or a substituted phenyl group.

16. The N^2-phosphinyl amidine compound of claim 1, wherein R^4 and R^5 are independently a phenyl group, a 2-substituted phenyl group, a 4-substituted phenyl group, a 2,4-disubstituted phenyl group, a 2,6-disubstituted phenyl group, a 3,5-disubstituted phenyl group, or a 2,4,6-trisubstituted phenyl group.

17. The N^2-phosphinyl amidine compound of claim 1, wherein

R^1 is a phenyl group or a substituted phenyl group,

R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, or a C_7 to C_{20} substituted aralkyl group,

R^3 is hydrogen, and

R^4 and R^5 are independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group.

18. The method of claim 2, wherein the metal amidinate of step a) is neutralized with a protic compound to form a non-metal amidine compound prior to step b).

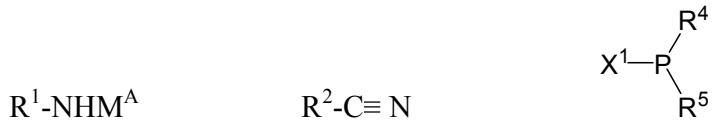
19. The method of claim 18, wherein the non-metal amidine compound is isolated and optionally purified and then contacted with a metal alkyl compound to form the metal amidinate.

20. The method of claim 2, wherein the metal amidinate of step a) is contacted with the phosphine halide without forming a non-metal amidine compound.

21. The method of claim 2, wherein the compound comprising the N^2-phosphinyl amidine group is isolated and optionally purified.

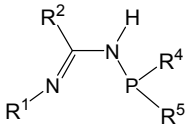
22. The method of claim 2, wherein the metal amide is formed by contacting an amine and a Group 1 or Group 2 metal alkyl.

23. The method of claim 2, wherein the metal amide has Structure MA1, the nitrile has Structure N1, the phosphine halide has the Structure PH1,



Structure MA1 **Structure N1** **Structure PH1**

and the compound comprising a N^2-phosphinyl amidine group is characterized by having the formula:



wherein

X^1 is selected from fluoro, chloro, bromo, and iodo,

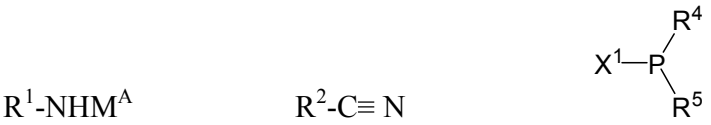
M^A is a Group 1 or Group 2 metal,

R^1 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group,

R^2 is a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof, and

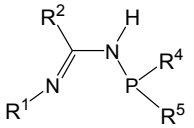
R^4 and R^5 are each independently a C_1 to C_{30} organyl group consisting essentially of inert functional groups wherein the inert functional groups are selected from the group consisting of halo groups, nitro groups, hydrocarboxy groups, sulfidyl groups, hydrocarbyl groups, or combinations thereof.

24. The method of claim 2, wherein the metal amide has Structure MA1, the nitrile has Structure N1, the phosphine halide has the Structure PH1,



Structure MA1 **Structure N1** **Structure PH1**

and the compound comprising a N^2-phosphinyl amidine group is characterized by having the formula:



wherein

M^A is a Group 1 or Group 2 metal,

X^1 is selected from fluoro, chloro, bromo, and iodo,

R^1 is a phenyl group or a substituted phenyl group,

R^2 is a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, a C_6 to C_{20} substituted aryl group, a C_7 to C_{20} aralkyl group, or a C_7 to C_{20} substituted aralkyl group; and

R^4 and R^5 are each independently a C_1 to C_{15} alkyl group, a C_4 to C_{20} cycloalkyl group, a C_4 to C_{20} substituted cycloalkyl group, a C_6 to C_{20} aryl group, or a C_6 to C_{20} substituted aryl group.

25. The metal salt complex of claim 3, wherein the metal salt comprises a Group 3-10 transition metal.

26. The metal salt complex of claim 3, wherein the metal of the metal salt is in a +2 or +3 oxidation state.

27. The metal salt complex of claim 3, wherein the metal salt comprises chromium.

28. The metal salt complex of claim 3, wherein the metal salt is a chromium(III) carboxylate, a chromium(III) β-diketonate, or a chromium(III) halide.

29. The metal salt complex of claim 3, wherein the metal salt is chromium(III) chloride.

30. The method of claim 4, wherein the transition metal salt and the N^2-phosphinyl amidine compound are contacted at a transition metal salt to N^2-phosphinyl amidine compound equivalent ratio of at least 0.9:1.

31. The method of claim 4, wherein the transition metal salt and the N^2-phosphinyl amidine compound are contacted in a solvent.