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COORDINATION COMPOUNDS CONTAINING TRIVALENT PHOSPHORUS COMPOUNDS AND CERTAIN METAL COMPOUNDS

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21 Claims

This application is a continuation-in-part of application Ser. No. 47,904, filed Aug. 8, 1960, now abandoned.

This invention relates to novel materials suitable for use as rocket propellants and jet fuels and as additives for use in these and allied fields. More particularly, the invention relates to solid and liquid rocket propellants; and liquid jet and internal combustion engine fuels and additives, and to methods for the preparation thereof.

While propellant fuels employed heretofore have produced an effective propulsive force when employed in jet and rocket engines, many compounds known to be capable of releasing significantly greater amounts of energy per unit and thus capable of effecting markedly enhanced propulsion when employed as fuels, have failed of general acceptance due to certain difficulties inherent therein. Illustrative of these compounds are the hydrides of boron, aluminum, beryllium, and the like. The principal disadvantages of these compounds have been their high cost and their difficulty in handling during manufacture, transportation, storage, and use. These compounds have also evidenced a very marked hydrolytic and pyrolytic instability requiring the complete exclusion of even the smallest traces of water and atmospheric oxygen from their presence. Further, these compounds are highly toxic in nature.

We have now discovered, however, compounds which are capable of effecting a propulsive force in rocket and jet engines approximately equivalent to that of the hydrides above referred to while avoiding substantially the difficulties inherent therein and alluded to above. A significant advantage of the propellant compounds of the present invention is the reduction in maximum flame temperature achieved thereby without diminution or loss of impulse thrust when employed in jet and rocket engines. These compounds also provide, as indicated above, valuable additives for use in jet and internal combustion engines.

Thus, the present invention involves the stabilization of metal hydrides and organometallic compounds by means of coordination between electron donor and electron acceptor molecules. For the preparation of high energy fuels by the practice described herein, the electron donor compounds comprise nitrogen and phosphorus containing compounds wherein the nitrogen and phosphorus moieties are in the trivalent state. Accordingly, and more elaborately, the compounds of the invention are therefore coordination complexes formed by virtue of a suitable electron donor-electron acceptor relation found to exist between trivalent phosphorus and nitrogen donor compounds, e.g. phosphine, mono-, di- and tri-aryl, alkyl and nitro phosphines, nitroalkyl, alkylene and alkenyl (e.g. vinyl) phosphines, nitrated derivatives of phosphines and alkyl phosphines, ammonia, mono-, di- and tri-alkyl, aryl, alkenyl and nitroalkyl amines, alkyl alkylene imines, alkylene imines (e.g. ethylene imine), polyamines, (e.g. alkylene diamines, such as ethylene diamine), hydrazine, mono- and di-alkyl hydrazines (e.g. dimethyl hydrazine), aniline, alkenyl, alkyl and aryl nitriles (e.g. acrylonitrile), and the electron acceptor compounds, that is, beryllium,

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lithium, magnesium, sodium, calcium, aluminum, potassium, silicon and boron hydrides, and the corresponding borohydrides and alkyl organometallic compounds of the aforesaid metals. These coordination complexes thus provide that compounds capable of high energy release upon combustion, which were, however, unsuitable for use as propulsion agents in rockets or jet engines hitherto because of their hydrolytic and/or pyrolytic instability, are now made sufficiently stable to permit the use of conventional handling techniques in manufacture, transportation, storage, use, and the like, thus permitting their employment as propulsive agents in high energy fuels.

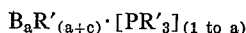
It is noted that the terms "alkyl," "alkylene," and "alkenyl" as employed herein are intended preferably to encompass the corresponding lower hydrocarbons wherein the number of carbon atoms is from 1 to 6 and most desirably from 1 to 3.

Thus, the novel metal hydride coordination compounds of the invention may be represented by the formulae: $M \cdot (X)_b$ and $Y \cdot (Z)_n$, wherein M is beryllium hydride, BeH_2 ; lithium hydride, LiH; magnesium hydride, MgH_2 ; aluminum hydride, AlH_3 ; lithium-aluminum hydride, $LiAlH_4$; beryllium borohydride, $Be(BH_4)_2$; lithium borohydride, $LiBH_4$; aluminum borohydride, $Al(BH_3)_3$; or magnesium borohydride, $Mg(BH_4)_2$; as well as aluminum beryllium hydride, lithium beryllium hydride, magnesium beryllium hydride, sodium borohydride, potassium borohydride and calcium borohydride; X is an alkylene (e.g. ethylene) phosphine,



alkenyl (e.g. vinyl) phosphine, $H_2PCH_2=CH_2$; an alkyl nitrate phosphine, such as methyl nitrate phosphine wherein the methyl nitrate substituents are within the range of 1 to 3; thus, mono-(methyl nitrate)-phosphine, $H_2PCH_2NO_3$; di(methyl nitrate) phosphine, $HP(CH_2NO_3)_2$; tri-(nitro-methyl) phosphine, $P[CH_2(NO_2)]_3$; tri(methyl nitrate) phosphine, $P(CH_2NO_3)_3$; a phosphine nitrate, or a mono- or di-nitro substituted phosphine, i.e., $H_2PNO_3HP(NO_2)_2$; phosphine, PH_3 ; a mono-di- or tri-alkyl or aryl phosphine, PR_3 , wherein R is an alkyl, aryl or nitro-substituted alkyl; ammonia, NH_3 ; a mono-, di- or tri-alkyl, nitro alkyl or aryl amine, $NH_2R(3_n)$ wherein R retains the same value as recited above; as well as an alkylene imine, alkyl alkylene imine, polyamine (e.g., hexamethylenetetramine, an alkylene diamine such as ethylene diamine), hydrazine, mono- or di-alkyl hydrazine, aniline, or an alkenyl, alkyl or aryl nitrile; Y is one of the aforesaid metal hydrides or metal borohydrides or organometallic compounds encompassed by M as recited above, or, in addition, may be a boron hydride or an alkyl derivative thereof containing within the range of 2 to 10 boron atoms, which boranes are encompassed by the formula, $B_nR'_{(a+c)}$ in which each of the R' substituents present is a hydrogen atom or an alkyl radical; and when the latter preferably a lower alkyl radical; a.g., diborane, B_2H_6 ; tetraborane, B_4H_{10} ; pentaborane, B_5H_9 , or decaborane, $B_{10}H_{14}$; Z is phosphine; ethylene phosphine, vinyl phosphine, a methyl nitrate phosphine wherein the methyl nitrate substituents attached to the phosphorus nucleus are within the range of 1 to 3; a phosphine nitrate; or a nitrophosphine again, most desirably, a mono- or di-nitro substituted phosphine, as defined above; ammonia, an alkyl amine, an alkyl alkylene amine, an alkylene imine, polyamine, hydrazine, di-alkyl hydrazine, aniline or an alkenyl, alkyl or aryl nitrile; b is an integer from 1 to 2 inclusive; n is an integer within the range of 1 to 10, and c is either 4 or 6. Other suitable electron acceptor compounds for use herein include the silicon hydrides. Each nitro-alkyl substituent where present contains preferably 1 to 2 nitro groups.

Other coordination compounds, which provide valuable propellants and fuel additives for use in accordance with the invention, are included among the borane-phosphines described in copending application Ser. No. 47,943 filed by the inventors herein on Aug. 8, 1960, now abandoned. Of these the borane-phosphines for use herein may be represented by the general formula:



wherein each of the R' substituents is a hydrogen atom or an alkyl radical, preferably a lower alkyl radical; a is an integer from 2 to 10 inclusive; and c is the integer 4 or 6. The expression, $(1 \text{ to } a)$, refers to the numerical value within the range of 1 to that of the integer symbolized by a as recited above; that is from 1 to 10 inclusive but not in excess of the value of a in any specific instance.

The term "borane" is utilized herein to encompass compounds formed of a plurality of boron atoms (i.e. 2 to 10 in number), having attached thereto hydrogen and/or alkyl substituents.

Illustrative of the novel hydride coordination compounds of the invention are aluminum borohydride-phosphine, beryllium borohydride-phosphine, lithium borohydride-methyl phosphine, lithium aluminum hydride-phosphine, aluminum borohydride-dimethyl phosphine, lithium borohydride-phosphine, beryllium hydride-ethylene phosphine, lithium hydride-mono-(methyl nitrate) phosphine, magnesium hydride-di(methyl nitrate) phosphine, aluminum hydride-tri(nitromethyl) phosphine, magnesium borohydride-phosphine nitrate, lithium aluminum hydride-dinitrophosphine, lithium hydride-vinyl phosphine, beryllium borohydride-ethylene phosphine, diborane-vinyl phosphine, tetraborane-vinyl phosphine, tetraborane-ethylene phosphine, tetraborane-di(methylnitrate) phosphine, tetraborane-phosphine nitrate, tetraborane-dinitrophosphine, pentaborane-ethylene phosphine, decaborane-di(methyl nitrate) phosphine, pentaborane-dinitrophosphine, lithium aluminum hydride-dimethyl amine, lithium aluminum hydride-hydrazine, aluminum borohydride-diethyl hydrazine, aluminum borohydride-monomethyl amine, aluminum borohydride-ethylene imine, aluminum borohydride-hydrazine, pentaborane-ethylene imine, tetraborane-monoethyl amine, diborane-polymerized ethylene amine, and beryllium borohydride-ammonia.

Illustrative of the borane-phosphines are pentaborane-diphosphine, $B_5H_9 \cdot (PH_3)_2$; decaborane-diphosphine, $B_{10}H_{14} \cdot (PH_3)_2$; pentaborane-di(trimethylphosphine), $B_5H_9 \cdot [P(CH_3)_3]_2$; decaborane-di(trimethylphosphine), $B_{10}H_{14} \cdot [H_2PCH_3]_2$; tetraborane-phosphine, $B_4H_{10} \cdot PH_3$; and tetraborane trimethylphosphine, $B_4H_{10} \cdot P(CH_3)_3$.

The propellant and fuel additive coordination compounds herein described are formed by admixture of a metal hydride as represented by the symbols M and Y in the above recited formulae with a phosphine encompassed by the symbols X and Z , respectively, of the aforesaid formulae. The preparation of borane-phosphines encompassed by the formula, $B_aR'_{(a+c)} \cdot [PR'_3]_{(1 \text{ to } a)}$, is described in the copending application Ser. No. 47,943, filed by the inventors herein on Aug. 8, 1960, now abandoned. In general, the procedure comprises reaction of boron hydrides or boranes as represented by the formula $B_aR'_{(a+c)}$ defined above, with a phosphine, PR'_3 , having the value ascribed thereto hereinabove. The mole ratio of hydride to phosphine in the reaction mixtures is within the range of 1:1 to 1:2 respectively; and normally substantially equimolar proportions of hydride and phosphine are utilized. The mole ratio of reactants, however, may be extended upward to 1:10, respectively. The reaction occurs preferably at a temperature within the range of -30°C. to 50°C. , and takes place most desirably in the presence of a suitable organic solvent, and particularly alkyl ethers, furans, and aliphatic and aromatic hydrocarbon solvents, such as, for example, diethyl ether, tetra-

hydrofuran, toluene, xylene, isooctane, and the like. The final products, the coordination compounds, like the reactants, are readily soluble in these solvents, and are indeed often incorporated in such media to facilitate handling when used particularly as additives for incorporation in internal combustion and jet propulsion engine fuels. The term "jet-propulsion," it should be noted, as employed throughout this specification and unless otherwise indicated, is intended to encompass rocket as well as jet-propulsion.

The coordination complexes are either liquids, solids, or polymerizable liquids, as where organometallic, organophosphorus or organonitrogen compounds are utilized which contain a polymerizable bond (e.g. a double bond); for example, where the phosphine or nitrogen containing constituent is polymerizable vinyl or ethylene phosphine, ethylene imine or allyl amine, the polymerizable compounds being capable after coordination of reaction to form their own solid matrices when employed as propellant fuels; these solid fuels being formed at the lowest feasible ratio of carbon to metal hydride, thus resulting in fuels capable of releasing substantially more energy in comparison with the standard carbon polymer binder which is of lower energy content than the coordination compounds containing polymerizable bonds, as referred to above. The liquid and solid complexes can be incorporated desirably nevertheless in such standard polymer binders, e.g. a polymerized hydrocarbon, in the practice of the invention.

The formulations of coordination compounds for use in jet or rocket fuel engines are therefore standard and assume a variety of forms. Thus, they may be varied to produce fuels which burn spontaneously when mixed with oxidizer; ignite upon injection into a hot chamber; undergo combustion upon being heated in the presence of a suitable oxidizer; or burn by means of ignition from an external source. Fuel burning rate, as well as the thrust generated, may be continuously varied under close control with the use of bipropellant and hybrid propellant forms. Monopropellant formulations can, of course, also be used effectively. In the bipropellant form, the fuel composition includes a liquid coordination compound and oxidizer, each of which is maintained separately from the other prior to use. The hybrid propellant form may be used with solid coordination complexes in which case the fuel composition will include, prior to use, some oxidizer, but its firing rate is controlled by a separate liquid oxidizer stream. By way of illustrating the foregoing methods, oxygen, for example, may be introduced into the fuel disposed, in situ, within the combustion chamber and the mixture ignited from an external source. Liquid or solid fuel is simply combined with the oxidizer in the monopropellant formulation. The oxidizers employed are conventional within the field and include, as noted, liquid and atmospheric oxygen, ozone, tetranitromethane, nitrogen trifluoride, chlorine, sodium nitrate, mixed oxides of nitrogen fluorine (gaseous), oxygen difluoride, nitrogen trifluoride, nitrogen difluoride monochloride, nitrogen trichloride, phosphorus nitrates, fluorine, nitric acid, ammonium perchlorate and mixed oxychlorates and perchlorates, peroxides, e.g. hydrogen peroxide, and oxonides; these materials being particularly well adapted to use in hybrid and bipropellant compositions. The mode of employment of the fuels of applicants is also conventional which is, indeed, one of the significant advantages residing in the present invention, as indicated above. Thus, if desired, they may be employed, for example, in the manner described in U.S. Pats. 2,777,739 and 2,896,403.

One of the principal difficulties known to exist in the use of metal-based fuels known heretofore is the relatively slow rate at which the metallic elements oxidize in these standard fuel formulations. This has resulted in much of such fuels leaving the combustion chamber or area unburned, thus greatly reducing their utility and

value. By the use of internal oxidizers in the monopropellant formulations proposed herein, the oxidation or burning rate of the metals can be controlled to give the desired combustion and the need for external oxidizer is substantially eliminated.

This combination of oxidizer and propellant is most desirably accomplished where monopropellant compositions are desired, however, by substitution on the carbon, nitrogen, or phosphorus elements of the fuels of the invention, e.g. in the phosphine and/or hydride moiety of the propellant coordination compound, of nitrate substituents and preferably methyl nitrate for hydrogen or hydrocarbyl substituents; the methyl nitrate thus providing the necessary oxidizer to cause combustion and substantially complete oxidation of the coordination complex and particularly the metallic portion thereof without the use of an external oxidizer, with consequent substantially complete utilization of the energy of the coordination complex and the metallic moiety thereof.

If a portion of the required oxidizer is included in the formulation of the solid fuel complex and is insufficient to maintain combustion, then a liquid oxidizer, for example, nitric acid, could be metered into the combustion chamber to initiate and continue combustion and maintenance of a controlled firing rate.

The fuels thus formed have been found to exhibit, as noted above, properties which obviate the deficiencies of their individual components (e.g. phosphine and a hydride) while retaining their advantages. Thus, stored or processed according to standard procedures, these compounds are found to be stable both to spontaneous pyrolysis and hydrolysis, relatively non-toxic due to a reduced vapor pressure and capable of storage for prolonged periods in the presence of atmospheric oxygen and moisture without visible deterioration. The chemical stability of these compounds is retained at temperatures well above those normally encountered in storage, handling and processing; nor will they dissociate due to shock or the like.

In addition, the complexes herein described and prepared are manifestly less expensive to produce over the boron-based fuels now receiving wide commercial application. At the same time, however, these compounds constitute fuels which adhere under conditions of use, such as, for example, in combination with suitable oxidizers if desired, heats of combustion within the range of 6000 to 7000 British thermal units (B.t.u.) per pound thereof.

Illustrative of the combinations of propellant and oxidizer compositions within the purview of the present invention are beryllium borohydride-phosphine and ammonium perchlorate; lithium aluminum hydride-hydrazine and fuming nitric acid; diborane-vinyl phosphine and liquid oxygen; magnesium hydride-dimethyl amine and tetranitromethane; aluminum borohydride-dimethyl hydrazine and gaseous fluorine; and aluminum hydride-ethylene imine and hydrogen peroxide. As indicated above, a propellant compound such as diborane-tri(nitromethyl)phosphine oxidizes well in the absence of any additional oxidizer. As also indicated above, the production of energy in the form of thrust, heat and/or light by oxidation of these compositions as well as the others described herein is effected in a standard manner and in any suitable and standard combustion chamber or area of an engine adapted for jet and rocket propulsion.

The following examples are further illustrative of the invention.

EXAMPLE 1

Preparation of beryllium borohydride-phosphine complex

To a solution of 3.87 grams (0.1 mole) of beryllium borohydride dissolved in 100 grams of tetrahydrofuran at 25° C. is passed phosphine gas (generated from Al-P and water) until absorption is complete. The solvent, tetrahydrofuran, is easily removed by distillation at 50° C. and 30 mm. Hg absolute pressure, leaving the phosphine-

beryllium borohydride coordination compound which is stable in moist air and is suitable for use as a component of a rocket propellant or a jet engine fuel.

EXAMPLE 2

Preparation of pentaborane-phosphine complex

Following the procedure of Example 1, to 6.41 grams (0.1 mole) of pentaborane dissolved in 100 grams of tetrahydrofuran is added phosphine gas until absorption at 25° C. is complete. After distilling off the solvent under vacuum, a stable coordination compound, pentaborane-phosphine, remains which is a suitable component of a jet engine fuel or rocket propellant.

EXAMPLE 3

Preparation of lithium aluminum hydride-phosphine complex

Following the procedure of Example 1, phosphine gas is passed into a solution of 3.80 grams (0.1 mole) of lithium aluminum hydride in tetrahydrofuran until one mole (3.4 grams) of phosphine has been absorbed. The product, after solvent removal, is the lithium aluminum hydride-phosphine complex which is stable in moist air, and is suitable for use as a component of a jet engine fuel, or rocket propellant.

EXAMPLE 4

Preparation of diborane-vinyl phosphine complex

To a solution of 12.20 grams (0.2 mole) of vinyl phosphine in 100 grams of tetrahydrofuran at -10° C. is passed 2.77 grams (0.1 mole) of diborane gas. At the completion of the reaction, the temperature is raised to 30° C. and the pressure reduced to 20 mm. Hg abs. to remove the solvent. The product is the stable diborane-divinyl phosphine complex to which other components and the stoichiometric quantity of oxidizer may be admixed and the resulting mixture polymerized in situ to form a solid rocket propellant.

EXAMPLE 5

Preparation of magnesium borohydride-ethylene phosphine complex

Following the procedure of Examples 1 and 4, to a solution of 5.40 grams (0.1 mole) of magnesium borohydride in 100 grams of tetrahydrofuran is added 6.00 grams (0.1 mole) of ethylene phosphine. The product, magnesium borohydride-ethylene phosphine complex may be polymerized with traces of acid to form stable polymers which, with other components and an oxidizer, may be used as a solid rocket propellant.

EXAMPLE 6

Preparation of beryllium hydride-dihydrogen phosphine nitrate complex

To a solution of 9.50 grams (0.1 mole) of dihydrogen phosphine nitrate in 100 grams of tetrahydrofuran at -10° C. is added 1.1 grams of beryllium hydride (0.1 mole). The complex, beryllium hydride-dihydrogen phosphine nitrate, remaining after removal of the solvent under vacuum is a suitable component of a liquid or solid fuel in which a part of the oxidizer is furnished by the complex.

EXAMPLE 7

Preparation of aluminum hydride-tri(methylene nitrate) phosphine complex

To a solution of 3.00 grams (0.1 mole) of aluminum hydride polymer dissolved in 100 grams of diethyl ether is added 25.91 grams (0.1 mole) tri(methylene nitrate) phosphine at 25° C. The solvent is removed by vacuum distillation leaving the stable aluminum hydride-tri(methyl nitrate) phosphine complex which may be

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utilized in a solid rocket propellant formulation in which a part of the oxidizer is contained in the complex.

EXAMPLE 8

Preparation of lithium aluminum hydride-dimethyl amine complex

To a solution of lithium aluminum hydride (LiAlH_4) (3.8 grams, 0.1 mole) dissolved in 200 grams of tetrahydrofuran at -30°C ., is added 4.5 grams (0.1 mole) of dimethyl amine. The mixture is allowed to warm to room temperature and is maintained at 26°C . for 96 hours, after which time the solvent, tetrahydrofuran, is removed in vacuo to yield lithium aluminum hydride-dimethyl amine which evidences upon elemental analysis:

Element	Found	Theory
Lithium.....	8.27	8.40
Aluminum.....	32.91	32.6
Carbon.....	28.23	28.9
Nitrogen.....	17.15	16.9

EXAMPLE 9

Preparation of lithium aluminum hydride-hydrazine complex

To a solution of lithium aluminum hydride (3.8 grams) dissolved in 200 grams of tetrahydrofuran, there is added, at -30°C ., 3.2 grams of hydrazine. The mixture is permitted to warm to room temperature and is maintained at 26°C . for 96 hours, after which time the solvent is removed in vacuo to yield lithium aluminum hydride-hydrazine in a substantially quantitative yield.

EXAMPLE 10

Preparation of aluminum borohydride-unsym. dimethylhydrazine complex

To a solution of 7.2 grams of aluminum borohydride, $\text{Al}(\text{BH}_4)_3$, dissolved in 200 grams of tetrahydrofuran, there is added 6.0 grams of unsymmetrical dimethyl hydrazine at -10°C . The mixture is permitted to warm to room temperature and is maintained at 26°C . for 96 hours, after which time the solvent, tetrahydrofuran, is removed in vacuo to result in a substantially quantitative yield of aluminum borohydride-unsym. dimethylhydrazine.

EXAMPLE 11

Preparation of aluminum borohydride-monomethyl amine complex

To a solution of 7.2 grams of aluminum borohydride, $\text{Al}(\text{BH}_4)_3$, dissolved in 200 grams of tetrahydrofuran, there is added 3.1 grams of monomethyl amine at 20°C . The mixture is permitted to warm to room temperature and is maintained at 26°C . for 72 hours, after which time the solvent, tetrahydrofuran, is removed in vacuo to result in a substantially quantitative yield of aluminum borohydride-monomethyl amine.

EXAMPLE 12

Preparation of aluminum borohydride-ethylene imine complex

To a solution of 7.2 grams of aluminum borohydride, $\text{Al}(\text{BH}_4)_3$, dissolved in 200 grams of tetrahydrofuran, there is added 4.3 grams of ethylene imine at 20°C . The mixture is permitted to warm to room temperature and is maintained at 26°C . for 72 hours, after which time the solvent, tetrahydrofuran, is removed in vacuo to result in a substantially quantitative yield of aluminum borohydride-ethylene imine.

EXAMPLE 13

Preparation of aluminum borohydride-hydrazine complex

To a solution of 7.2 grams of aluminum borohydride, $\text{Al}(\text{BH}_4)_3$, dissolved in 200 grams of tetrahydrofuran, there is added 3.2 grams of hydrazine at -30°C . The

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mixture is permitted to warm to room temperature and is maintained at 26°C . for 72 hours, after which time the solvent, tetrahydrofuran, is removed in vacuo to result in a substantially quantitative yield of aluminum borohydride-hydrazine.

EXAMPLE 14

Preparation of pentaborane-ethylene imine complex

In a similar manner, to a solution of 6.4 grams of pentaborane B_5H_9 dissolved in 200 grams of tetrahydrofuran, there is added 4.3 grams of ethylene imine. The product secured in substantially quantitative yield is pentaborane-ethylene imine.

EXAMPLE 15

Preparation of tetraborane-monoethyl amine complex

In a similar manner, to a solution of 5.4 grams of tetraborane, B_4H_{10} , dissolved in 200 grams of tetrahydrofuran, there is added 4.3 grams of monoethyl amine. The product secured in substantially quantitative yield is tetraborane-monoethyl amine.

EXAMPLE 16

Preparation of diborane-ethylene diamine complex

In a similar manner, to a solution of 2.8 grams of diborane, B_2H_6 , dissolved in 200 grams of tetrahydrofuran, there is added 6.0 grams of ethylene diamine. The product secured in substantially quantitative yield is diborane-ethylene diamine.

EXAMPLE 17

Preparation of beryllium borohydride-acrylonitrile complex

In a similar manner, to a solution of 3.9 grams of beryllium borohydride, $\text{Be}(\text{BH}_4)_2$, dissolved in 200 grams of tetrahydrofuran, there is added 5.3 grams of acrylonitrile. The product secured in substantially quantitative yield is beryllium borohydride-acrylonitrile.

EXAMPLE 18

Preparation of magnesium hydride-dimethylamine complex

In a similar manner, to a solution of 2.63 grams of magnesium hydride, MgH_2 , dissolved in 200 grams of tetrahydrofuran, there is added 4.5 grams of dimethyl amine. The product secured in substantially quantitative yield is magnesium hydride-dimethyl amine.

EXAMPLE 19

Preparation of diborane-tri(nitromethyl) phosphine complex

In a similar manner, employing diborane and tri(nitromethyl)phosphine, there is prepared the coordination compound, diborane-tri(nitromethyl)phosphine.

EXAMPLE 20

Preparation of aluminum hydride-ethylene imine complex

In a similar manner to that described in the foregoing examples, there is prepared, employing aluminum hydride and ethylene imine as the reactants, the coordination compound, aluminum hydride-ethylene imine.

What is claimed is:

1. A coordination compound composed of a trivalent phosphorus compound as an electron donor compound and an electron acceptor compound selected from the group consisting of a metal hydride and a corresponding borohydride and organo metallic constituent of said metal wherein the metal is selected from the group consisting of beryllium, lithium, magnesium, sodium, calcium, aluminum and potassium.

2. The coordination compound beryllium borohydride-phosphine.

3. The coordination compound lithium aluminum hydride-phosphine.
4. The coordination compound diborane-vinyl phosphine.
5. The coordination compound magnesium borohydride-ethylene phosphine.
6. The coordination compound beryllium hydride-dihydrogen phosphine nitrate.
7. The coordination compound aluminum hydride-tri(methylene nitrate)phosphine.
8. The coordination compound lithium aluminum hydride-dimethyl amine.
9. The coordination compound lithium aluminum hydride-hydrazine.
10. The coordination compound aluminum borohydride-dimethylhydrazine.
11. The coordination compound aluminum borohydride-monomethyl amine.
12. The coordination compound aluminum borohydride-ethylene imine.
13. The coordination compound aluminum borohydride-hydrazine.
14. The coordination compound pentaborane-ethylene imine.
15. The coordination compound tetraborane-mono-vinyl amine.
16. The coordination compound diborane-ethylene diamine.

17. The coordination compound beryllium borohydride-acrylonitrile.
18. The coordination compound magnesium hydride-dimethyl amine.
- 5 19. The coordination compound diborane-tri(nitromethyl)phosphine.
20. The coordination compound aluminum hydride-ethylene imine.
- 10 21. The coordination compound pentaborane-phosphine.

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