This invention relates to novel hydrocarbon group III-A element compounds and to a process for their preparation.

Attendant with the development and evolution of the internal combustion engine for passenger car and heavy-duty service, the petroleum industry has been continually called upon to effect improvements in the antiknock quality of hydrocarbon fuels. These improvements have, in general, been brought about by two distinct methods. One of these methods comprises improvements in refining operations such as thermal and catalytic cracking and reforming or alkylating processes. The other method comprises the use of fuel additives to effect an increase in the antiknock qualities of the hydrocarbon fuels. Inasmuch as improvements in refinery techniques involve considerable capital expenditures, the use of fuel additives has attained greater and more widespread acceptance as the more effective method, particularly from the economic standpoint. The instant invention is therefore concerned with providing novel hydrocarbon group III-A element compounds suitable for use in the manufacture of hydrocarbon manganese compounds useful as additives to fuel and lubricating oils and also useful in the synthesis of other manganese compounds which are capable of improving combustion characteristics of hydrocarbon fuels and as additives to lubricating oils and greases, and the like.

It is therefore an object of our invention to provide novel hydrocarbon group III-A element compounds. It is also an object of this invention to provide such compounds for manufacture of hydrocarbon manganese compounds which are useful as additives to solid combustion fuels, and lubricating oils and greases, as well as for other uses. It is likewise an object to provide a process for the preparation of novel hydrocarbon group III-A element compounds. Additional important objects of this invention will become apparent from the discussion which follows.

The above and other objects are accomplished by providing novel tris(hydrocarbon cycloalkyl) group III-A element compounds in which the cycloalkatic hydrocarbon radicals have from 5 to about 17 carbon atoms and which embody a group of 5 carbon atoms having the general configuration found in cyclopentadienyl.

More specifically, the compounds of this invention have the general formula:

$$R_3M$$

wherein $R$ is a cycloalkatic radical as defined above and $M$ is a group III-A element. The compounds of this invention can be made by a number of processes.

One suitable process is to react the group III-A element with a cycloalkatic compound of the metal which is solid at the temperature of the reaction, such as the lower solid carbonates. For example, tris(cyclopentadienyl) aluminum can be made by reacting aluminum metal with bis(cyclopentadienyl) mercury. This reaction can be carried out at temperatures of from about -50° to 250° C., preferably in the range of 90° to 100° C. The specific temperature to be employed depends somewhat on the thermal stability of the reactants and the upper temperature is usually limited by the rate of decomposition of the reactants or product. The process is best carried out in inert solvent system. Particularly useful solvents are hydrocarbons, including aliphatic, aromatic and cycloaliphatic, chlorinated hydrocarbons, ethers, amines and acetals. In most cases the reaction is preferably conducted with an inert atmosphere, frequently maintained at moderate pressure, since some of these compounds are susceptible to air oxidation or react with water.

Another very suitable method for the preparation of the compounds of this invention comprises the reaction of alkali metal cycloalkatic compounds with aluminum compounds, e.g. aluminum salts such as aluminum halides, alcoholates, alkanoates, and the like. This reaction can be conducted under the same general conditions as those defined above. Another process comprises the use of alkaline earth metal cycloalkatic compounds with the same aluminum compounds, including the use of Grignard reagents, such as cyclopentadienyl magnesium halides.

Another suitable process for the manufacture of the compounds of this invention involves the reaction of an activated form of a group III-A element with the cycloalkatic hydrocarbon directly. Thus, activated aluminum or other group III-A metal in highly subdivided form can react with a cyclopentadienyl hydrocarbon to form the tris(cyclopentadienyl) hydrocarbon group III-A element compound. In this process, a particularly desirable modification involves the initial activation of the metal with a quantity of tris(cycloalkatic) hydrocarbon group III-A element compound. More specifically, the direct reaction of cycloalkatic hydrocarbon with a group III-A element is conducted in the presence of a quantity of pre-prepared tris(cycloalkatic) hydrocarbon group III-A element compound. In actual practice the process can be conducted continuously or batch-wise such that only a portion of the tris(cycloalkatic) hydrocarbon compound is used. A metal product is removed from the reactor and a portion of the product remains in the reactor with excess metal for further reaction with additional cycloalkatic hydrocarbon.

When employing the compounds of our invention for use in the synthesis of other hydrocarbon metal compounds, e.g. manganese compounds, we especially prefer compounds in which at least one of the carbon-to-carbon double bonds in the cyclopentadienyl-group configuration is olefinic in nature. In other words, if the cycloalkatic ring should be shared with a fused aromatic ring such as a benzene ring. An example of one of the cycloalkatic radicals of this type of embodiments is the indenyl radical. When compositions of this invention having cycloalkatic radicals, with the above described characteristics, are employed in producing cycloalkatic manganese compounds, the resultant manganese compounds are found to have highly desirable characteristics when used as fuel and lubricating additives.

Reference to the generic formula described above indicates that there are two types of constituents in the new composition of matter of the present invention. These are, first, the cycloalkatic radicals $R$, which can be the same or different and, second, the elemental constituents B, Al, Ga, In and Tl. As stated previously, the cycloalkatic radicals $R$ are cyclopentadienyl-type radicals, i.e., radicals consisting of the cyclopentadienyl group.

In general, such cycloalkatic groups can be represented by the four generic formulae presented hereinafter, having from 5 to about 17 carbon atoms. Thus, any substituents attached to the cyclopentadienyl group in the radical can have from 1 to about 12 carbon atoms. However, radicals in which the substituent group 1 to about 20 or more carbon atoms are also within our invention.

When a cycloalkatic radical is substituted with univalent
aliphatic radicals, these substituents can be radicals having from 1 to about 12 or more carbon atoms selected from the group consisting of alkyl, alkenyl, aralkyl and aralkeny1. Thus, when these substituents are univalent aliphatic radicals, they can be alkyl radicals, such as methyl, ethyl, n-propyl, isopropyl, n-butyl, isobutyl, sec-butyl, n-amyl, the various positional isomers thereof, as for example, 2-methylbutyl; 1,1-dimethylpropyl; 1-ethylpropyl, and the corresponding straight and branched chain isomers of hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, tetradecyl, hexadecyl, nonadecyl, eicosyl, and the like. Likewise, the univalent aliphatic substituent can be an alkynyl radical, such as ethynyl, A'-propenyl, A'-2-propenyl, isopropenyl, A'-2-butynyl, A'-2-butenyl, and the branched chain isomers thereof as A'-2-isobutenyl, A'-3-isobutenyl, A'-3-butenyl, A'-3-butenyl, A'-2-sec-butenyl, A'-pentenyl, A'-2-pentenyl, and the branched chain isomers thereof A'-hexenyl, A'-hexenyl, A'-hexynyl, and the branched chain isomers thereof, including 3,3-dimethyl-A'-butenyl; 2,3-dimethyl-A'-butenyl; and 1-methyl-1-ethyl-A'-2-propenyl, and the various isomers of heptenyl, octenyl, noneynyl, decenyl, undecenyl, dodecenyl, tetradecenyl, heptadecenyl, octodecenyl, eicosenyl, and the like.

When the organic radical substituted in the cyclomatic group is a univalent aliphatic radical, it can be an arylalkyl radical such as, for example, benzyl, a-phenylethyl, a-acetoxyethyl, a-phenylisopropyl, a-phenylisobutyl, a-phenylisopropyl, a-phenylisobutyl, a-phenyll-t-butyl,a-5-naphthyl methyl, a-4-naphthylmethyl, a-(a'-naphthyl)-ethyl, A'-5-(a'-naphthyl)-ethyl, a-(a'-naphthyl)-propyl, a-(A'-5-naphthyl)-isopropyl, a-(a'-naphthyl)-isobutyl, a-(A'-5-naphthyl)-sec-butyl, the corresponding A'- and A'-5-naphthyl derivatives of n-amyl, and the like. Other such arylalkyl radicals include the a', a'-5, a'-5-and a'-anthryl derivatives of aryl radicals, such as a', a'-anthrylmethyl, a-(A'-5-anthryl)-ethyl, A'-5-(A'-5-anthryl)-2-methylamyl, and the like; and the corresponding alkyl derivatives of phenanthrene, fluorene, acenaphthene, chrysene, pyrene, triphenylene, naphthalene, etc. The univalent arylalkyl radical can be an arylalkenyl radical, such as a-phenylethenyl, a-phenylethyl, a-phenyl-A'-prophenyl, and the phenyl derivatives of the isomers of butenyl, pentenyl, and the like, the sum a and b can be the same or different and is selected from the group consisting of hydroxy and organic hydrocarbon radicals having from 1 to about 12 or more carbon atoms. Illustrative examples of such cyclomatic radicals include cyclopentadienyl; methylcyclopentadienyl; 1,2-dimethylcyclopentadienyl; ethylcyclopentadienyl; 1,3,4-tripropylcyclopentadienyl; 1,5-dipentylcyclopentadienyl; 1-methyl-3-t-butylcyclopentadienyl; isopropenylcyclopentadienyl; 1,2-di(5-5-5) cyclopentadienyl; 1-methyl-3-(A'-pentenyl) cyclopentadienyl; 3-(β-phenylethyl)-cyclopentadienyl; 3-cyclohexylcyclopentadienyl; 2-phenyl-3-(α-phenyl-ethyl)-cyclopentadienyl; 2-phenyl-3-(α-phenyl-ethyl)-cyclopentadienyl; 2- (α-tolyl-cyclopentadienyl); 1-acetyl-cyclopentadienyl; and the like.

The second type of cyclomatic radical is the indenyl-type radical represented by the general formula

wherein each of R1, R2, R3, R4, R5 and R6 can be the same or different and is selected from the group consisting of hydroxy and organic hydrocarbon radicals having from 1 to about 12 or more carbon atoms. Illustrative examples of such cyclomatic radicals include indenyl; 2-methylindenyl; 3-sec-butylindenyl; 3,4-dienylindenyl; 5-(a-phenylbutyl)-indenyl; 3-cyclohexylindenyl; 3-phenylindenyl; 4,5-diphenylindenyl, and the like.

The third type of cyclomatic radical of the new compositions of matter of the present invention is a radical of the fluorenyl type which can be represented by the general formula

wherein each of R7, R8, R9, R10, R11 and R12 can be the same or different and is selected from the group consisting of hydroxy and organic hydrocarbon radicals having from 1 to about 12 or more carbon atoms. Illustrative examples of such radicals include fluorenyl; 3-ethylfluorenyl; 4,5-dipropyl fluorenyl; 9-methylfluorenyl; 6-ethenylfluorenyl; 4-benzylfluorenyl; 2-m-tolylfluorenyl, and the like.

The fourth type of cyclomatic radical, that is, a radical containing the cyclopentadienyl moiety can be represented by the general formula

wherein a and b can be the same or different and are small whole integers including 0 and excluding 1, the sum a+b being at least 2, and wherein Rx is selected from the class consisting of hydrogen and organic radicals. Thus, when a is zero each of the carbon atoms designated as 2 and 3 have attached thereto a monovalent
radical selected from the class consisting of hydrogen and organic radicals. Furthermore, the monovalent radicals so attached can be the same or different. The same discussion applies to each of the carbon atoms designated as 4 and 5 when b is zero. Illustrative examples of this type of cyclomatic radical include 4,5,6,7-tetraydroindenyl; 1,2,3,4,5,6,7,8-octahydrofluorenyl; 3-methyl-4,5,6,7-tetraydroindenyl, and the like.

Non-limiting examples of the compounds of this invention in which the cyclomatic radical has the configuration shown in Structure I above are tris(cyclopentadienyl) boron; tris(methylcyclopentadienyl) boron; tris(ethylcyclopentadienyl) boron; tris(propylcyclopentadienyl) boron; tris(butylcyclopentadienyl) boron; tris(t-butylcyclopentadienyl) boron; tris(1,2-diphenylcyclopentadienyl) boron; tris(1,2,3,4-tetramethylcyclopentadienyl) boron; tris(1,2,3,4,5-pentamethylcyclopentadienyl) boron; tris(1,3-diphenylcyclopentadienyl) boron; tris(3,5-diphenylcyclopentadienyl) boron; tris(3-acetylcyclopentadienyl) boron; bis(cyclopentadienyl) (methylcyclopentadienyl) boron; cyclopentadienyl-bis(indenyl) boron; tris(cyclopentadienyl) aluminum; tris(methylcyclopentadienyl) aluminum; tris(ethylcyclopentadienyl) aluminum; tris(propylcyclopentadienyl) aluminum; tris(butylcyclopentadienyl) aluminum; tris(1,2-diphenylcyclopentadienyl) aluminum; tris(1,3-diphenylcyclopentadienyl) aluminum; tris(3,5-diphenylcyclopentadienyl) aluminum; tris(decyldicyclopentadienyl) aluminum; tris(1,2,3,4-tetramethylcyclopentadienyl) aluminum; tris(1,2,3,4,5-pentamethylcyclopentadienyl) aluminum; tris(3,5-diphenylcyclopentadienyl) aluminum; tris(3-acetylcyclopentadienyl) aluminum; bis(cyclopentadienyl) (3,5-diphenylcyclopentadienyl) aluminum; bis(3-acetylcyclopentadienyl) aluminum; cyclopentadienyl-bis(indenyl) aluminum; tris(1,2-diphenylcyclopentadienyl) gallium; tris(3,5-diphenylcyclopentadienyl) gallium; tris(1,2-diphenylcyclopentadienyl) indium; tris(3,5-diphenylcyclopentadienyl) indium; tris(3-acetylcyclopentadienyl) indium; tris(1,2-diphenylcyclopentadienyl) thallium; tris(3,5-diphenylcyclopentadienyl) thallium; tris(1,2-diphenylcyclopentadienyl) thallium, and the like.

Other examples of compounds having the configuration of Structure II given hereinafter are tris(indenyl) boron; tris(3-methylindenyl) boron; tris(3-ethylindenyl) boron; tris(3-propylindenyl) boron; tris(3-butylindenyl) boron; tris(1,2-dipropylindenyl) boron; tris(1,2,3,4,5,6,7-heptamethylindenyl) boron; tris(1,2,3,4,6,7-heptamethylindenyl) boron; tris(3-methylindenyl) aluminum; tris(3-ethylindenyl) aluminum; tris(2,3-dimethylindenyl) aluminum; and the like.

Other examples of compounds having the configuration of Structure III above are tris(fluorenyl) boron; tris(3-ethylfluorenyl) aluminum; tris(4-propylfluorenyl) aluminum; tris(2,3,4,7-tetramethylfluorenyl) aluminum, and the like.

Examples of compounds having the configuration of Structure IV above are tris(4,5,6,7-tetraydroindenyl) aluminum; tris(1,2,3,4,5,6,7,8-octahydrofluorenyl) aluminum; tris(1,4,5,8-tetraydroindenyl) aluminum, and the like.

The reaction is preferably carried out in the presence of a suitable, preferably non-aqueous, solvent, examples of which are hydrocarbons, such as benzene, cyclohexane, isobutylene, and ethers, such as ethereal ether, ethylene glycol dimethyl ether, ethylene glycol diethyl ether, propylene glycol methylphenyl ether, methylphenyl ether, tetrahydrofuran, dioxane, decenyl ether, etc. In other words, hydrocarbon and ether solvents having up to about 20 carbon atoms may be employed.

The cyclomatic group III-A element products can be separated from the reaction mixture by solution in a solvent, such as ether, and the removal of the solid impurities by filtration, centrifugation, and the like. The product can also be separated from the reaction mixture by vacuum distillation or selective solvent extraction. The solvent may be removed from the product by fractional distillation and the product further purified by fractional distillation or sublimation. The method of preparation is further illustrated in the examples below.

When the tris(cyclomatic) metal compounds of the invention are employed to form cyclomatic manganese compounds, a wide variety of manganese salts can be used for this reaction.

The manganese salts employed are salts of organic or inorganic acids, preferably the respective manganese salts. Examples of these manganese salts are manganese acetate, manganese benzoate, manganese carbonate, manganese oxalate, manganese lactate, manganese nitrate, manganese phosphate, manganese sulfate, manganese perchlorate, manganese fluoride, manganese chloride, manganese bromide, manganese iodide, and the like. In addition, manganese salts of &beta;-diketones, such as tris(2,4-pentanedione) manganese and tris(2,4-hexanedione) manganese may also be employed, as well as manganese salts of &beta;-keto esters, such as the manganese salts of ethylacetoacetate and the like. An example of the process employed is the reaction of tris(cyclopentadienyl) aluminum with manganese halide to give bis(cyclopentadienyl) manganese. Cyclomatic group III-A element compounds are also reacted with naturally occurring manganese ores, such as manganosite, manganese dioxide (MnO₂), manganese sesquioxide (Mn₃O₄), manganese sulfide (MnS), manganese sulfide (Mn₃S₄), rhodochrosite (MnCO₃), and the like, to give bis(cyclomatic) manganese compounds such as bis(methylcyclpentadienyl) manganese, etc.

EXAMPLE I
Tris(cyclopentadienyl) aluminum

To a reaction vessel equipped with a stirrer and a thermometer, and previously purged with dry nitrogen was added 8.1 parts (0.032 mol) of finely ground aluminum metal. The aluminum was treated with a diethyl ether solution of anhydrous hydrogen chloride for the purpose of cleaning and activating the surface of the aluminum. The reaction was allowed to continue until all of the metal became dispersed in the foamy mixture. The ether was then removed by three washings with toluene and finally 120 parts of toluene was added as a solvent for the reaction.

With stirring, 25 parts (0.0755 mol) of bis(cyclopentadienyl) mercury was then added which had been previously prepared according to the method of Wilkinson and Piper, J. Inorg. Nucl. Chem., 2, 32 (1956), from dicyclopentadienyl sodium and mercuric chloride. After a 30-
minute addition period during which the temperature rose as high as 45° C., stirring was continued for an additional hour at room temperature. A test for mercuric ion in solution was negative.

The reaction mixture was then centrifuged to remove suspended aluminum. Solvent was removed by evaporation at room temperature.

There was obtained 10.7 parts (95.6% yield) of the grey solid tris(cyclopentadienyl)aluminum which melted at 50°-60° C. It was soluble in benzene and toluene. A portion, on exposure to air, did not spontaneously inflame. Instead, it gradually whitened, indicating formation of aluminum oxide and hydroxide due to attack of atmospheric oxygen and moisture. Upon treatment with water, white aluminum hydroxide was formed. This was soluble in dilute acid. The product on aging, stored under nitrogen, showed no tendency to discolor or change in character. The analysis of the product showed 12.1 percent aluminum, the theoretical being 12.24 percent.

The tris(cyclopentadienyl)aluminum (1 mole) prepared above is reacted with stoichiometric quantities of anhydrous manganese chloride at 165° C. In diethylene glycol dimethyl ether (1 mole). The reaction mixture was stirred throughout the reaction. The bis(cyclopentadienyl)manganese so formed is thereafter reacted with carbon monoxide (500 p.s.i.g.) at 190° C. to produce cyclopentadienyl manganese tricarbonyl. This product, after purification by distillation, is then blended in gasoline (0.2 gram manganese metal/gal. of gasoline) to raise the octane number of the gasoline 2 octane numbers.

EXAMPLE II
Tris(methylcyclopentadienyl)aluminum

Example I is repeated except that bis(methylcyclopentadienyl)mercury is employed instead of bis(cyclopentadienyl)mercury and the aluminum was activated by being employed in excess in the previous example. In this example, benzene is employed as the solvent. The tris(methylcyclopentadienyl)aluminum is recovered in good yield.

EXAMPLE III
Tris(indenyl)aluminum

Example I is repeated except that bis(indenyl)mercury is employed instead of bis(cyclopentadienyl)mercury, and hexane is employed as the solvent. Very satisfactory yields of the tris(indenyl)aluminum are obtained.

EXAMPLE IV
Tris(cyclopentadienyl)boron

100 parts of cyclopentadienyl sodium dissolved in 1000 parts of tetrahydrofuran are added to 26 parts of boron trifluoride. This reaction mixture is then heated to 50° C. and the reaction mixture stirred for one hour. The reaction is thereafter centrifuged to remove the solid sodium chloride and the tetrahydrofuran is evaporated from the tris(cyclopentadienyl)boron. This product is recovered in excellent yield.

EXAMPLE V
Tris(fluorenyl)gallium

Fluorenyl magnesium bromide (80.7 parts) dissolved in 800 parts of diethyl ether is added to 17.6 parts of gallium trichloride dissolved in 50 parts of diethyl ether. The reaction mixture is heated for one hour at reflux temperature and the tris(fluorenyl)gallium is recovered, as in Example IV, in good yield.

EXAMPLE VI
Tris(n-octyclopentadienyl)indium

Indium metal (11.5 parts) is added to 200 parts of n-octyclopentadiene. The indium metal was pretreated with aluminum triethyl to activate the metal. The activation is conducted at 70° C. and the indium metal is separated from the excess aluminum triethyl and transferred to the reaction vessel containing the n-octyclopentadiene under an inert atmosphere. This reaction mixture is then heated to a temperature of 125° C. for five hours and the tris(n-octyclopentadienyl)indium is thereafter recovered in excellent yield by distilling off the excess n-octyclopentadiene at 1 mm. Hg pressure.

EXAMPLE VII
Tris(cyclopentadienyl)thallium

Example I is repeated except that thallium metal (allowed 5% of its weight of copper metal) is reacted with tris(cyclopentadienyl)zinc. The thallium metal is deployed in a 3-mole excess. The reaction is conducted in dicyclobexylamine solvent at a temperature of 110° C. The tris(cyclopentadienyl) thallium is recovered as a complex with the amine solvent.

EXAMPLE VIII
Bis(cyclopentadieny1)methylcyclopentadienyl aluminum

A mixture of cyclopentadienyl sodium (2 moles) and methylcyclopentadienyl sodium (1 mole) is dissolved in diethylene glycol dibuty1 ether and reacted with aluminum in accordance with the procedure of Example I. A good yield of bis(cyclopentadienyl) methylcyclopentadienyl aluminum is obtained.

EXAMPLE IX
Cyclopentadienyl lithium

Cyclopentadienyl lithium was obtained by preparing n-butyl lithium and reacting this compound with cyclopentadiene. According to this process, 68.5 parts of n-butyl bromide was added to 8.6 parts of lithium metal in anhydrous diethyl ether at a temperature of 0°-10° C. The resultant ether solution of n-butyl lithium was filtered and then added to 20.4 parts of cyclopentadiene in ether. The product, cyclopentadienyl lithium settled out as a white solid, the completion of the reaction being evidenced by the cessation of butane evolution. The procedure followed in the above synthesis was that described in Organic Reactions, volume VI, pp. 352-353, John Wiley and Sons, Inc., New York (1951).

Tricyclopentadienyl boron

The cyclopentadienyl lithium in ether, prepared as above, was slowly added with agitation to 15.2 parts of anhydrous boron trichloride dissolved in 91 parts of anhydrous diethyl ether and contained in a vessel equipped with openings for charging and discharging liquids and fluids, means for refluxing liquids, temperature measuring devices, means for regulating temperature, and fitted with a mechanical agitator. The reaction resulted in the formation of an orange colored product. The ether-soluble product was removed from the unreacted ether-insoluble cyclopentadienyl lithium by filtration. Ammonia was bubbled through the ether solution to remove any unreacted boron trichloride which settled out as a solid amnonia addition compound. The ether layer was evaporated leaving an orange solid. This product turned blue-green on exposure to air. The ratio of the percentage by weight of carbon to the total of carbon, hydrogen and boron is 86 percent, which indicates that the product obtained in this reaction is (C5H8)3B, calculated 87 percent carbon.

Equally good results are obtained when the teaching of the above example is employed in reacting other cyclopentadienyl-type alkali metal compounds with boron trihalides as, for example, the reaction between 1-methyl cyclopentadienyl sodium with boron tribromide in benzene to produce tris(1-methyl cyclopentadienyl)boron, the reaction between 5-phenyl cyclopentadienyl potassium with boron tribromide in anhydrous anisole to produce tris(5- phenyl cyclopentadienyl)boron, the reaction between indenyl rubidium with boron triiodide in a solvent com-
posed of a mixture of diethyl ether, benzene, and hexane to produce trilindienyl boron, and the like.

Tris(2-benzyl cyclopentadienyl)aluminum can be obtained by the reaction of 2-benzyl cyclopentadienyl potassium with aluminum chloride.

This application is a continuation-in-part of our co-pending application, Serial No. 297,392, filed July 5, 1952 and application Serial No. 417,920, filed March 22, 1954.

We claim:

1. A cyclopentadienyl element compound having the general formula:

\[ R_M \]

wherein R is a cyclopentadienyl hydrocarbon group and M is a group III-A element, the element M being bonded to a cyclopentadienyl ring carbon of the cyclopentadienyl group, said cyclopentadienyl group containing from 5-17 carbon atoms.

2. The compound of claim 1 wherein the element is aluminum.

3. Tris(cyclopentadienyl)aluminum.

4. Tris(methycyclopentadienyl)aluminum.

5. The compound of claim 1 wherein the element is boron.

6. Tris(cyclopentadienyl)boron.

7. Tris(methycyclopentadienyl)boron.

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