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PROCESS AND PRODUCT FOR THE PRODUCTION OF LOW-CARBON CHROMIUM ALLOYS

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This invention relates to metallurgy and has for an object the provision of improved metallurgical processes and products. More particularly, the invention contemplates the provision of improved products and methods or processes for use in the production of low-carbon chromium alloys. The invention further contemplates the production of improved reaction mixtures comprising chromite ore and suitable for use in the production of low-carbon chromium alloys. A further object of the invention is to provide certain improvements in metallurgical methods or processes employing chromite ore in the production of low-carbon chromium alloys.

It has been proposed heretofore to produce low-carbon chromium alloys such as chromium-bearing iron and steel by reduction of the iron and chromium compounds of the ore with non-carbonaceous reducing agents. Reaction mixtures or charges of the type proposed heretofore have been effective for the reduction of the iron and chromium of chromite ore when smelted in electric furnaces, but the use of such mixtures in combustion heated furnaces has not been highly successful. Even when reaction mixtures of the type proposed heretofore have been smelted successfully for reduction of the iron and chromium, the results obtained have not always been entirely satisfactory because of relatively high contents of carbon and residual reducing agent present in the metal products formed.

My investigations have demonstrated that the efficiency of reduction of iron and chromium of chromite ores and control of residual reducing agent in the metal products formed may be improved by providing for more intimate contact of the components of the mixture and by providing exothermicity of a degree such that the chromite ore is subjected to the action of the reducing agent in a softened or molten condition. My investigations have demonstrated also that carbon pick-up with resulting contamination is attributable, in part at least, to carbon present as organic carbon or in carbonate form or as both organic carbon and carbonate carbon in the chromite ore, and I have found that more effective control of carbon in the metal products formed can be accomplished by treating the chromite ore to effect carbon removal prior to incorporating the ore in the reaction mixture.

A desirable degree of intimate mixing may be accomplished by employing the components in the form of particles of suitably small sizes. In accordance with the invention, particles of suitably small sizes may be obtained by subjecting the ore in solid, finely divided form to an oxidizing operation to effect oxidation of a portion of the chromium to the hexavalent condition. Such partial oxidation of the chromium takes place on the outer surfaces of the particles with the result that the residual chromite ore particles are smaller in size than the ore particles initially subjected to oxidation. Intimate mixing is promoted also by dispersing an oxidizing agent such as a nitrate or a chromate widely throughout the reaction mixture as by wetting the components with a solution of the oxidizing agent or with the oxidizing agent in a molten condition. Any chromate employed as an oxidizing agent may be produced by oxidizing a portion of the chromite ore to reduce the particle size or it may be provided from a separate source. Improved exothermicity is promoted by intimate mixing and by careful adjustment of reagents in the reaction mixture. Control of exothermicity in producing exothermic reaction mixtures of the invention may be accomplished advantageously by adjusting the proportions of components of the mixtures in accordance with the principles and procedures described in my copending applications Serial Nos. 301,375 and 301,376, filed October 26, 1939.

Carbon removal may be effected by an oxidation treatment carried out at a temperature sufficiently high to effect combustion of organic carbon and decomposition of any carbonate present. Carbonate carbon may be removed also by treatment of the ore in finally divided form with a dilute aqueous solution of an acid such as sulphuric acid. Usually both organic carbon and carbonate carbon can be removed effectively by heating finely divided chromite ore in air, or in the presence of any suitable solid or gaseous oxidizing agent or material containing oxygen available for reaction with the organic carbon, to a temperature of about 1000° C. For carbon removal, the chromite ore preferably is ground or comminuted to convert it to the form of particles small enough to pass a 100-mesh screen, and the ore is subjected to the carbon removal treatment in the resulting finely divided or powdered form.

When a portion of the chromium of the chromite ore is to be converted to the hexavalent condition (chromate form) by oxidation, the ore to be subjected to the oxidizing treatment preferably is ground or comminuted to produce a finely divided product consisting largely of particles small enough to pass a 100-mesh screen. Oxidation of the chromite ore may be carried out in accordance with known procedures to produce a product containing desired chromate compounds such, for example, as calcium chromate and sodium chromate. An oxidation or roasting charge may comprise chromite ore, lime and an alkali metal compound, such as sodium carbonate, sodium chromate or sodium dichromate, all in finely divided forms and in intimate admixture and in proportions such as to effect the desired conversion of chromium to the hexavalent state and the production of calcium chromate and alkali metal chromate in the desired proportion. Roasting or oxidation may be carried out in air effectively at temperatures up to about 1000° C. In a preferred method of producing exothermic reaction mixtures in accordance with the invention, oxidation is controlled to prevent complete conversion of the trivalent chromium of the chromite ore to the hexavalent state. Usually, conversion of not more than about fifty percent of the chromium of the chromite ore to the hexavalent state can be carried out to produce effective reduction in size of the original small particles of chromite ore and to produce chromate compounds which contribute effectively to the exothermicity of any reaction mixture of the invention in which the roasted or oxidized product may be employed. The roasting or oxidation results in conversion of the chromium of the surface portions of the chromite ore particles to chromate compounds, leaving small cores or nuclei of unaltered chromium ore. These small nuclei or cores of chromite ore are admirably suited for use in promoting the accomplishment of the degree of intimate mixing of components of exothermic reaction mixtures which provides optimum reacting conditions.

Any suitable non-carbonaceous reducing agent may be employed in forming an exothermic reaction mixture in accordance with the invention. For reasons of economy, I prefer to employ silicon or a silicide, and, when it is desired to increase the quantity of metallic chromium produced upon ignition of a reaction mixture over that capable of being produced by reduction of the chromite ore, I prefer to employ ferrochrome silicon (FeCrSi).

In producing various exothermic reaction mixtures in accordance with the invention, any suitable oxidizing material capable of reacting with the non-carbonaceous reducing agent to develop a suitably high temperature higher than the temperature capable of being developed by reaction of the reducing agent with the reducible iron and chromium compounds of the chromite ore may be employed. The oxidizing material may comprise a compound, such as sodium nitrate or sodium chlorate, which is free of any metallic element reducible to the elemental state by the reducing agent, or, it may comprise a compound containing a metallic element reducible to the elemental state by the reducing agent such, for example, as sodium chromate, sodium dichromate and calcium chromate. When it is desired to increase the quantity of metallic chromium produced by reaction over that capable of being produced by reduction of the reducible compounds of the chromite ore, I prefer to employ oxidizing material comprising a chromate compound.

Exothermic mixtures produced in accordance with the invention may contain sufficient lime to result, upon ignition and reaction, in the production of a fluid slag by combination with the acid slag-forming material such as silica produced by the reaction, or, lime (CaO) in amount suitable for producing slag of the desired composition may be added to the furnace or other reaction vessel. Lime included in a reaction mixture should be chemically combined with acid slag-forming material such, for example, as the iron oxide, alumina and chromic oxide of the chromite ore, to prevent water and carbon dioxide pick-up from the atmosphere if the reaction mixture is to be stored for any substantial period of time prior to use. Chemical combination of the lime with the constituents of the ore may be effected by heating the lime and the chromite ore in finely divided forms and in intimate admixture to an elevated temperature. A temperature of about 1000° C. produces effective chemical combination when the lime and ore particles are small enough to pass a 100-mesh screen.

Exothermic reaction mixtures may comprise (1) natural chromite ore in finely divided, but otherwise untreated form, (2) chromite ore in finely divided form which has been treated for the removal of organic and carbonate carbon but which has not been subjected to oxidation to convert chromium contained therein to the hexavalent state or (3) chromite ore contained in chromate-bearing oxidized material resulting from oxidation of finely divided chromite ore to convert trivalent chromium to the hexavalent state and to reduce the sizes of the chromite ore particles comprising the initial roasting or oxidation charge. Any combination of treated and untreated chromite ore-bearing products may be incorporated in a reaction mixture of the invention. Oxidation of the chromite ore to produce hexavalent chromium results also in elimination of organic and carbonate carbon. When untreated ore, or ore untreated otherwise than for carbon removal, is employed, it is advisable to employ the reaction mixtures in the form of solid agglomerates in which the components are intimately mixed with and bonded together by means of the oxidizing material. Bonding of the components of the reaction mixtures by means of the oxidizing material produces highly desirable intimate mixing of the oxidizing material and the other components by effecting thorough wetting or coating of the other components with the oxidizing material. Reaction mixtures comprising chromite ore-bearing and chromate-bearing oxidized products may be employed effectively in powdered form, packaged form or as agglomerates in which the particles are bonded together by the oxidizing material or by other suitable material.

In the preferred exothermic reaction mixtures of the invention, all reacting materials preferably are present in the form of particles small enough to pass a 100-mesh screen. When the oxidizing material functions as the bonding agent for other components in an agglomerate, it is widely disseminated throughout the agglomerate in the form of thin films or coatings on the solid particles of other components.

An exothermic reaction mixture of the invention comprises solid, finely divided chromite ore; solid, finely divided non-carbonaceous reducing material capable of reacting with compounds of iron and chromium contained in the chromite ore to produce metallic iron and metallic chromium; and oxidizing material capable of reacting exothermically with the reducing material to develop a temperature higher than that resulting from reaction of the reducing material with compounds of iron and chromium contained in the chromite ore. Preferably, the components of the reaction mixture are present in such quantities and are so proportioned that the reducing material is capable upon ignition of the reaction mixture of reacting with the oxidizing material to generate sufficient heat to melt the chromite ore and promote reduction of the iron and chromium compounds of the ore by the reducing material, and the reducing material is present in the reaction mixture in an amount sufficient to react with all of the oxidizing material and a large proportion of the iron and chromium compounds of the ore.

The exothermic reaction mixtures of the invention preferably are of such compositions as to be capable upon ignition on the surface of a molten bath of metal such as iron or steel of delivering to the molten metal of the bath molten low-carbon ferrochromium. The reaction mixtures may be of such compositions as to be capable, upon ignition in a previously unheated environment, of producing molten low-carbon ferrochromium by means of self-propagating reactions. The heat developing capacity of any reaction mixture produced in accordance with the invention preferably will be determined on the basis of the contemplated use of the reaction mixture. For example, if the reaction mixture is to be placed on the surface of a molten bath of metal, such as iron or steel, at a relatively high temperature and containing excess heat available for melting or for aiding in melting ore, metal present as such in the mixture and any metal which may be produced by reaction upon ignition of the mixture, the components of the reaction mixture may be so selected and proportioned as to provide a relatively low heat developing capacity. If, on the other hand, the reaction mixture is to be placed on the surface of a relatively cold bath of molten metal containing no available excess heat for melting or for aiding in melting ore and metal, or, if the reaction mixture is to be placed on the surface of a bath of molten metal the temperature of which should be increased, or, if the reaction mixture is to be ignited in a previously unheated environment, the components of the reaction mixture may advantageously be so selected and proportioned as to provide a relatively high heat developing capacity in order to melt the ore, metal present as such and any metal which may be produced by reaction upon ignition of the mixture and to establish the molten metal at the desired temperature. By providing exothermic reaction mixtures capable of delivering molten ferrochromium by reaction upon ignition, the necessity of employing only the higher grades of ores as sources of chromium is eliminated since the danger of chilling molten metal by the addition of solid metal is eliminated. Thus, the invention makes available as sources of chromium ores of all grades which can be smelted commercially to produce metal products containing iron and chromium.

In proper cases, reaction mixtures of the invention may be agglomerated in any suitable manner as by means of an inert bonding agent such as sodium silicate or by means of an agent such as an oxidizing agent capable of taking part in reactions with other components. I prefer to form agglomerates by employing oxidizing materials capable of functioning as bonding agents for the particles of the mixtures. The oxidizing agents may be employed in finely divided condition or they may be employed in the molten state or in the solid state resulting from solidification from the molten state, or resulting from precipitation or crystallization from solution, after mixing with the other components. Bonding by means of the oxidizing agents may be of the type effected through the application of high pressures to quantities of the mixtures; it may be of the type effected through moistening, as with an aqueous liquid, compacting and heating to drive off moisture; or it may be of the type effected by solidification of the oxidizing agents from the molten state in contact with the other components. Contact of the other components of the reaction mixtures with the oxidizing agents while molten or in solution causes effective wetting and coating of the other components with the oxidizing agents and provides for more effective reaction upon ignition. When an oxidizing agent is employed in the solid state resulting from solidification from the molten state, or precipitation or crystallization from solution, it serves as a bonding agent for bonding together in intimate association the other components of the mixture. Reaction mixtures containing calcium chromate or sodium chromate or both may be effectively agglomerated through the bonding action of the sodium chromate or calcium chromate or both by moistening the mixtures with water, molding agglomerates under pressure and heating the agglomerates to temperatures sufficiently high to drive off free end combined water.

The oxidizing agent employed in forming reaction mixtures when fusion is to be carried out should be selected to insure a fusing point below the temperatures at which ignition of the mixture, with resulting reaction, will take place. Oxidizing agents having suitably low fusing or melting temperatures include many of the oxygen-bearing compounds of alkali metals such, for example, as sodium nitrate, sodium chlorate and sodium bichromate. Other oxidizing agents which may be employed in forming the reaction mixtures when incorporation of chromium or manganese in the resulting product is sought, include calcium chromate, sodium chromate and manganese dioxide.

Agglomerates in which the oxidizing material serves as the bonding agent may be produced in any suitable manner. The components which enter into the reactions upon ignition, such as the silicon-containing material, the oxidizing material and the chromite ore may be ground together to effect intimate mixing, and the resulting mixture may be heated to a temperature sufficiently high to effect fusion of the oxidizing agent without igniting the reaction mixture. Fusion may be carried out in vessels or pans of the sizes and shapes of the agglomerates sought to be produced, in which case the agglomerates may be permitted to cool and solidify in place, or, fusion may be carried out in a master vessel, and the fused mass may be poured into suitable molds for cooling and solidification. Materials, such as metals and any silicides which do not enter into reactions resulting from ignition, if such materials are to be included in agglomerates, may be stirred into the reaction mixtures immediately prior to fusion or after fusion and while the oxidizing material is still molten.

In bonding together the components of a reaction mixture by means of the oxidizing material, I may moisten the mixture with an aqueous liquid, form the resulting wet mass into agglomerates under pressure and heat the agglomerates to drive off the water. This procedure produces strong solid agglomerates in many cases even when the agglomerates are heated to a temperature below the fusing temperature of any low fusing point oxidizing agent which may be present in the mixture. Amounts of water equal to about two to three (2 to 3%) percent of the mixture may be employed satisfactorily for wetting a mixture. Wetting and molding may be desirable even when fusion of an oxidizing component of a mixture is to be carried out.

Solid agglomerates of the invention produced by fusing and solidifying the oxidizing materials in contact with the other components and solid agglomerates produced by heating agglomerates of moistened reaction mixtures without fusion provide excellent carriers for materials to be melted by heat developed upon ignition of the mixtures. The agglomerates are very hard and compact and they effectively hold relatively large pieces of metal in the effective reaction zones until they are melted by heat developed in the course of the reactions.

The following examples illustrate reaction mixtures and processes of the invention employing chromite ore and ferrochrome silicon of the compositions indicated below:

Ore:	Percent
Cr_2O_3	44.0
FeO	23.8
Al_2O_3	13.8
MgO	8.1
SiO_2	6.8
CaO	3.0

Ferrochrome silicon:	Percent
Chromium	28.00
Silicon	48.50
Iron	23.49
Carbon	.01

Example I

A batch of ore of the above composition was ground to form a finely divided product consisting largely of particles small enough to pass a 100-mesh screen. The ground product was roasted in air at an elevated temperature between 750° C. and 1000° C. to effect substantially complete elimination of organic carbon and carbonate carbon but without converting trivalent chromium of the ore to the hexavalent state.

An exothermic mixture was formed by grinding together the roasted ore product, anhydrous calcium chromate ($CaCrO_4$) and ferrochrome silicon in the following proportions by weight:

	Parts
Roasted ore product	100
Calcium chromate	100
Ferrochrome silicon	102

The resulting mixture was moistened with water in an amount equal to about two to three (2 to 3%) percent of the weight of the mixture formed into agglomerates by molding under pressure, and the agglomerates were heated to a temperature of about 500° C. to drive off free and combined water. The resulting agglomerates were compact, hard and strong. (The reaction mixture may be employed satisfactorily in either powder form or agglomerated form.)

Chromium steel was produced by melting 1650 pounds of scrap and pig, eliminating carbon to the desired extent with iron oxide, clearing the slag of iron oxide by adding ferrosilicon and lime and, thereafter, adding 880 pounds of the reaction mixture to the molten metal. Reaction was initiated immediately. Lime was added to adjust the lime-silica ratio of the slag to about 1.3:1. The metal was tapped about twenty-five minutes after addition of the reaction mixture. The steel produced analyzed twelve (12%) percent chromium, indicating a recovery of about ninety (90%) percent of the chromium of the reaction mixture.

In employing such a reaction mixture for the production of chromium steel, the reaction mixture may be added before or after removal of the melting down slag. The composition of the slag with respect to lime and silica preferably is adjusted to establish a lime-silica ratio of from 1:1 to 1:1.5 by adding lime after the reaction has been completed. The reaction is fast but not violent.

Example II

A roasting or oxidation charge was formed by grinding together chromite ore, lime (CaO) and sodium carbonate (Na_2CO_3) in the following proportions by weight to form a finely divided product consisting largely of solid particles small enough to pass a 100-mesh screen:

	Parts
Chromite ore	100
Lime (CaO)	25
Sodium carbonate (Na_2CO_3)	15

The finely divided charge thus formed was roasted in air at a maximum temperature of 1000° C. to produce a roasted product containing slightly more than fifty (50%) percent of the chromium of the chromite ore in the form of chromates of sodium and calcium and in which all lime present was chemically combined with oxides of iron, chromium and aluminum.

An exothermic mixture was formed by grinding together the oxidized product thus produced with ferrochrome silicon in the following proportions by weight:

	Parts
Oxidized product	147.5
Ferrochrome silicon	67.4

The resulting reaction mixture was agglomerated in accordance with the procedure followed in Example I above. (The reaction mixture may be employed satisfactorily in either powder form or agglomerated form.)

Chromium steel was produced by melting 1542 pounds of scrap and pig, eliminating carbon to the desired extent with iron oxide, clearing the slag of iron oxide by adding ferrosilicon and lime and, thereafter, adding 1210 pounds of the reaction mixture to the molten metal. After completion of the reaction, the steel analyzed 12.2% chromium indicating a recovery slightly higher than ninety (90%) percent.

Example III

A reaction mixture was formed by grinding together chromite ore (treated to effect carbon removal as described in Example I above), sodium nitrate ($NaNO_3$) and ferrochrome silicon in the following proportions by weight:

	Parts
Roasted chromite ore	100.0
Sodium nitrate	30.6
Ferrochrome silicon	56.6

The resulting mixture was moistened with water in an amount equal to about two to three (2 to 3%) percent of the weight of the mixture, formed into agglomerates by molding under pressure, and the agglomerates were heated to a temperature slightly above the melting temperature of sodium nitrate to melt the sodium nitrate and drive off water. The resulting agglomerates were compact, hard and strong.

Chromium steel was produced by melting scrap and pig, eliminating carbon to the desired extent with iron oxide, clearing the slag of iron oxide by adding lime and ferrosilicon and, thereafter, adding a calculated quantity of the reaction mixture. The reaction mixture reacted rapidly but not violently to produce steel having the desired chromium content, and the chromium recovery exceeded ninety (90%) percent.

I claim:

1. A reaction mixture suitable for use in the production of chromium alloys which comprises finely divided, solid particles of chromite ore and finely divided, solid particles of non-carbonaceous reducing material capable of reacting with compounds of iron and chromium contained in the chromite ore to produce metallic iron and metallic chromium intimately associated with and bonded together by means of oxidizing material capable of reacting exothermically with the reducing material to develop a temperature higher than that resulting from reaction of the reducing material with compounds of iron and chromium contained in the chromite ore.

2. A reaction mixture suitable for use in the production of chromium alloys which comprises finely divided, solid particles of chromite ore and finely divided, solid particles of non-carbonaceous reducing material capable of reacting with compounds of iron and chromium contained in the chromite ore to produce metallic iron and metallic chromium intimately associated with and bonded together by means of oxidizing material capable of reacting exothermically with the reducing material to develop a temperature higher than that resulting from reaction of the reducing material with compounds of iron and chromium contained in the chromite ore, the components of the reaction mixture being present in such quantities and being so proportioned that the reducing material is capable upon ignition of the reaction mixture of reacting with the oxidizing material to generate sufficient heat to melt the chromite ore and promote reduction of the iron and chromium compounds of the ore by the reducing material and the reducing material being present in the reaction mixture in an amount sufficient to react with all of the oxidizing material and a large proportion of the iron and chromium compounds of the ore.

3. A reaction mixture suitable for use in the production of chromium alloys which comprises finely divided, solid particles of chromite ore and finely divided, solid particles of silicon-containing reducing material intimately associated with and bonded together by means of sodium nitrate, the components of the reaction mixture being present in such quantities and being so proportioned that silicon of the reducing material is capable upon ignition of the reaction mixture of reacting with the sodium nitrate to generate sufficient heat to melt the chromite ore and promote reduction of the iron and chromium compounds of the ore by silicon of the reducing material and the silicon of the reducing material being present in the reaction mixture in an amount sufficient to react with all of the sodium nitrate and a large proportion of the iron and chromium compounds of the ore.

4. A reaction mixture suitable for use in the production of chromium alloys which comprises finely divided, solid particles of chromite ore and finely divided, solid particles of ferrochrome silicon intimately associated with and bonded together by means of sodium nitrate, the components of the reaction mixture being present in such quantities and being so proportioned that silicon of the ferrochrome silicon is capable upon ignition of the reaction mixture of reacting with the sodium nitrate to generate sufficient heat to melt the chromite ore and promote reduction of the iron and chromium compounds of the ore by silicon of the ferrochrome silicon and the silicon of the ferrochrome silicon being present in the reaction mixture in an amount sufficient to react with all of the sodium nitrate and a large proportion of the iron and chromium compounds of the ore.

5. A reaction mixture suitable for use in the production of chromium alloys which comprises finely divided, solid particles of chromite ore and finely divided, solid particles of silicon-containing reducing material intimately associated with and bonded together by means of one or more chromate compounds including calcium chromate, the components of the reaction mixture being present in such quantities and being so proportioned that the silicon of the reducing material is capable upon ignition of the reaction mixture of reacting with the one or more chromate compounds to generate sufficient heat to melt the chromite ore and promote reduction of the iron and chromium compounds of the ore by silicon of the reducing material and the silicon of the reducing material being present in the reaction mixture in an amount sufficient to react with all of the one or more chromate compounds and a large proportion of the iron and chromium compounds of the ore.

6. A reaction mixture suitable for use in the production of chromium alloys which comprises finely divided, solid particles of chromite ore and finely divided, solid particles of ferrochrome silicon intimately associated with and bonded together by means of one or more chromate compounds including calcium chromate, the components of the reaction mixture being present in such quantities and being so proportioned that silicon of the ferrochrome silicon is capable upon ignition of the reaction mixture of reacting with one or more chromate compounds to generate sufficient heat to melt the chromite ore and promote reduction of the iron and chromium compounds of the ore by silicon of the ferrochrome silicon and the silicon of the ferrochrome silicon being present in the reaction mixture in an amount sufficient to react with all of the one or more chromate compounds and a large proportion of the iron and chromium compounds of the ore.

7. In a process for producing low-carbon chromium alloys involving the treatment of chromite ore with a non-carbonaceous reducing agent under conditions such as to effect reduction of iron and chromium compounds contained in the ore to metallic iron and metallic chromium, the improvement which comprises subjecting the chromite ore to an oxidizing treatment in the presence of lime to remove carbon contained therein and oxidize a portion of the chromium to the hexavalent condition with the production of calcium chromate prior to treatment with the reducing agent, oxidation being so controlled as to convert not more than about fifty percent of the chromium to the hexavalent condition.

8. The method of producing a reaction mixture suitable for use in the production of chromium alloys which comprises subjecting chromite ore to an oxidizing treatment in the presence of lime

to remove carbon therefrom and convert a portion of the chromium to the hexavalent condition with the production of calcium chromate, oxidation being so controlled as to convert not more than about fifty percent of the chromium to the hexavalent condition, and mixing the resulting product with ferrochrome silicon.

9. In a process for producing low-carbon chromium alloys involving the treatment of chromite ore with a non-carbonaceous reducing agent under conditions such as to effect reduction of iron and chromium compounds contained in the ore to metallic iron and metallic chromium, the improvement which comprises subjecting the chromite ore to an oxidizing treatment in the presence of lime to remove carbon contained therein and oxidize a portion of the chromium to the hexavalent condition with the production of calcium chromate prior to treatment with the reducing agent, oxidation being so controlled as to convert a portion only of the chromium to the hexavalent condition.

10. The method of producing a reaction mixture suitable for use in the production of chromium alloys which comprises subjecting chromite ore to an oxidizing treatment in the presence of lime to remove carbon therefrom and convert a portion of the chromium to the hexavalent condition with the production of calcium chromate, oxidation being so controlled as to convert a portion only of the chromium to the hexavalent condition, and mixing the resulting product with a silicon-containing reducing agent.

11. A reaction mixture suitable for use in the production of chromium alloys which comprises (1) solid, finely divided material resulting from the oxidation of chromite ore in the presence of lime and containing calcium chromate and unaltered chromite ore and (2) solid, finely divided reducing material containing silicon.

12. The method of incorporating chromium in molten metal such as iron and steel which comprises reacting in contact with the molten metal a reaction mixture comprising (1) solid, finely divided material resulting from the oxidation of chromite ore in the presence of lime and containing calcium chromate and unaltered chromite ore and (2) solid, finely divided reducing material containing silicon.

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