

UNITED STATES PATENT OFFICE

2,193,364

PROCESS FOR OBTAINING BERYLLIUM AND
BERYLLIUM ALLOYSCarlo Adamoli, Milan, Italy, assignor to Perosa
Corporation, Wilmington, Del., a corporation
of DelawareNo Drawing. Application April 17, 1939, Serial
No. 268,385. In Italy June 6, 1936

16 Claims. (Cl. 75-84)

The present application relates to a process for directly obtaining in a single operation starting from halogenated compounds containing beryllium, beryllium as such or in the state of alloys with one or more alloyed elements capable of alloying with beryllium, and is a continuation-in-part of my prior application Ser. No. 144,411 filed on May 24, 1937.

In my said prior application, I have disclosed a process for directly obtaining in a single operation beryllium or beryllium alloys starting from simple beryllium fluoride anhydrous and free or substantially free from oxide. The present invention relates more particularly to a process of manufacture of beryllium or beryllium alloys starting from normal double fluoride of beryllium and an alkali-metal, the term "normal" being intended to designate double fluorides containing two molecules of alkali fluoride for one molecule of beryllium fluoride.

It is known how many difficulties of chemical, thermal and technical nature are presented by the problem of effecting by direct reaction starting from beryllium compounds, the production of beryllium alloys with determined contents, in particular of a high beryllium content, as well as of pure beryllium.

It has never been possible up to now despite numerous attempts, to effect with industrial yields the production of beryllium and of its alloys by thermo-chemical treatment of beryllium compounds.

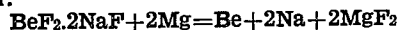
The difficulties of chemical and thermal nature met with in decomposing beryllium compounds arise in particular from the fact that the exchange reactions which take place are very quickly checked or give rise to the formation of products which hinder them being carried out under the conditions in which it is desired to operate. From the technical point of view these difficulties are increased by the lightness of the beryllium which tends to float upon the slag and to be maintained separate from any heavy metal present, by the high melting point of beryllium and by its great tendency to be oxidized or to form carbides.

In the presence of all these difficulties it has been proposed to use electrolytic processes for replacing thermo-chemical treatments, but none the less without arriving, by reason in particular of the necessarily very high cost of the manufacture, at obtaining industrial results and being able to effect this manufacture upon an industrial scale.

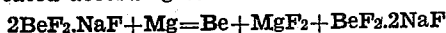
One is thus brought back to the thermo-chem-

ical method for the production of beryllium and its alloys by treatment with a decomposing bivalent metal such as magnesium, of a fluorine-containing compound of beryllium, that is a double fluoride of beryllium and an alkali metal (sodium) less rich in sodium fluoride than the normal double fluoride $\text{BeF}_2 \cdot 2\text{NaF}$.

The practical impossibility in fact has been established which is met with in operating with the normal double fluoride according to the reaction:



which is rendered explosive by reason of the liberation of sodium and this is the reason in particular why instead of the normal double fluoride $\text{BeF}_2 \cdot 2\text{NaF}$ the complex fluoride $\text{BeF}_2 \cdot \text{NaF}$ is treated according to the reaction:



This reaction would seem to be rendered possible here by the fact that the sodium fluoride and magnesium fluoride formed are present in a ratio such that the reversibility of the reaction which would lead to the setting free of sodium is prevented. However, as seen, the reaction thus effected does not lead to the liberation in the metallic state of more than half the beryllium contained in the compound treated, the other half of beryllium remaining in the residue, in the form of a complex compound from which the said beryllium may be extracted for example in the form of double fluoride. From this there results a large diminution of the yield of the operation and a corresponding increase in the net cost of the manufacture.

Thus the processes known up to now have not permitted a solution of the problem of the industrial manufacture of beryllium and its alloys.

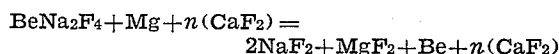
This problem is solved nevertheless in a simple and practical manner by the present invention and that in conditions where there is effected in a direct and complete manner and with a high yield practically reaching 100%, the production of beryllium, either as such or in the state of alloys with predetermined contents, whatever these may be, and in particular with a beryllium content above 25% or as high as is desired.

Although none of the known processes permitted practically complete reactions to be effected, the new process which forms the subject of the invention permits such quantitative reactions to be regularly effected and obtained, while allowing alloys of beryllium with determined contents, or pure beryllium to be obtained with practically total maximum yield.

The process according to the invention consists in bringing together a normal double fluoride of beryllium and an alkali metal and a quantity which practically corresponds stoichiometrically with the beryllium contained in said double fluoride, of an element or of a mixture of elements capable of reducing the beryllium fluoride to beryllium, in the presence of or in admixture with a halide of another metal, preferably at least bivalent, such as magnesium fluoride or an alkaline earth metal fluoride, and in heating the whole until the reaction of the beryllium fluoride is substantially complete.

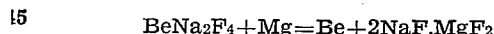
The interest in the presence of such a fluoride of an alkaline earth metal or magnesium in the case where a normal beryllium and alkali double fluoride is treated, may be explained by the fact that this alkaline earth or other fluoride acts as a neutralizer preventing the setting free, during the reaction, of the alkali metal of the double fluoride treated, and, due to the fact that just the necessary stoichiometrical proportion of the reducing element is caused to act, there is thus effected an integral displacement of the beryllium of the compound treated without danger of setting free alkali metal (for example sodium).

Thus for example, in the case where the normal double fluoride of beryllium and sodium is treated in the presence of calcium fluoride with magnesium as the decomposing element, the operation follows the reaction:



the (CaF_2) added acting as a neutralizer due to which all the sodium remains fixed by the fluorine in the form of NaF .

By thus utilizing for extracting all beryllium from a molecule of BeNa_2F_4 , a single molecule of Mg (instead of two molecules of Mg which would necessitate the corresponding reaction when liberating sodium) there has been effected under the optimum conditions the quantitative reaction:



To sum up, the utilization of a fluoride of a bivalent metal, such as an alkaline earth metal or magnesium, in presence of which the operation is carried out, prevents the setting free of sodium or other alkali metal which the compound of beryllium treated may contain, due to the fact that it tends to decompose preferentially to sodium fluoride and by its tendency to set free fluorine it favours a reaction which ensures the fixation of the fluorine by the sodium in the form of NaF in particular.

As reducing elements there may be used any metals which are more electropositive than the beryllium, such for example as magnesium, or elements which have a great affinity for the fluorine such for example as aluminium, silicon or boron.

The complete exchange reaction is effected by a simple fusion operation. For this purpose one may mix for example in the cold the reacting materials: normal double fluoride of beryllium and an alkali metal and reducing elements and simply melt them together, this single fusion operation ensuring the complete chemical transformation by double exchange which is effected if the stoichiometrical proportions have been used, without having recourse to any special operation means. The operation may be effected advantageously in an electric induction furnace

such as a high frequency furnace, though the invention is not confined to such an operating method.

Instead of using as the original beryllium compound only a normal double fluoride of beryllium and an alkali metal, one may use a mixture of simple beryllium fluoride and such a double fluoride, provided that the reaction is effected according to this invention in the presence of a neutralizer preventing the setting free of the alkali metal of the double fluoride. It should be also stated that the beryllium fluoride to be utilised is an anhydrous fluoride practically free from oxide, as described in our copending application Serial No. 144,411 above mentioned.

When the beryllium is required in the state of an alloy the reaction is performed in the presence of the element or elements to be alloyed with the beryllium. Said element or elements may be mixed or preferably alloyed with the reducing agent, or they may be introduced in the reaction mixture in the form of compounds reducible by the reducing agent, in which case the reducing agent is used in a quantity which corresponds stoichiometrically with the beryllium and with the element or elements to be alloyed with the beryllium. In the case of obtaining beryllium alloys it may be of interest to add to the slags alkali or alkalised salts which are not oxygenated, such for example as fluorides and chlorides, in order to modify the fusibility of the slags according to the nature of the alloys to be obtained.

The proportions of reacting materials to be employed according to the invention may be determined by calculation to effect the desired quantitative reactions.

If: A, is the quantity of beryllium fluoride treated;

B, the quantity of beryllium alloy to be obtained;

a, the beryllium content of the beryllium compound treated;

b, the beryllium content of the alloy to be obtained;

C, the quantity of reducing element to be caused to act;

E, the chemical equivalent of beryllium;

e, the chemical equivalent of the reducing element employed, the necessary proportions of reacting materials, which should be approached as closely as possible are the following:

The quantity A of the beryllium compound to be decomposed is determined by the expression:

$$A = B \times \frac{b}{a}$$

The quantity C of the reducing element necessary to be employed is determined by the equation:

$$C = \frac{B \times b}{100} \times \frac{E}{e}$$

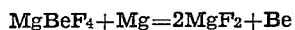
One may thus say that there is caused to act upon the beryllium compound (which is in quantity equal to the quantity of beryllium to be obtained divided by the beryllium content of this compound) a quantity of reducing element which is practically equal to the quantity of beryllium to be set free multiplied by the ratio of the chemical equivalents of the beryllium and of the reducing element. As reducing elements to be caused to act upon the beryllium fluoride to be decomposed, there are used elements which

are more electro-positive than beryllium either singly or in a state of mixture or in the state of compounds liberating during the reaction the decomposing elements aforesaid. The better results are obtained with metals of the group comprising the alkali metals (for example Na, K, Li) the alkaline earth metals (for example Ca, Ba, Sr) Rb, Ce and magnesium; the metals which are more clearly electro-positive than beryllium being of the greatest importance. However, very satisfactory results have likewise been obtained with certain elements which though less electro-positive than beryllium, have a great affinity for the fluorine such for example as aluminium, silicon or boron.

Among the bivalent metals besides the alkaline earth metals magnesium is particularly advantageous as decomposing element. When magnesium for example is caused to act upon the double fluoride of beryllium and sodium the decomposition of the latter takes place first at about 900° C. according to an intermediary reaction giving a double fluoride of beryllium and magnesium, for example:



then, according to a second double exchange reaction (at about 1100° C.) which is much more active than the first and takes place according to the reaction:



By introducing into the mixture an excess of sodium salt a mixture of low melting point is formed with the magnesium fluoride which is produced which facilitates to a large extent the agglomeration of the beryllium into a compact state.

To obtain by the process according to the invention alloys of beryllium with a beryllium content varying as desired between less than 1% and up to nearly 100% it is suitable to cause the reducing metals to act in the presence of the metal or metals or possibly metalloids to be alloyed with the beryllium or even metallic compounds capable of providing during the course of the reaction the alloying element or elements.

The desired contents of the final alloy to be obtained are obtained by the fact that there is employed a quantity of alloying element exactly proportioned to the proportion of this body that the final alloy should contain.

In general the reducing metals or metalloids are caused to act either in the presence of the element or elements to be alloyed with the beryllium or in the state of mixtures or alloys with them.

As elements capable of being employed more particularly as alloying elements for the reducing elements one may use in particular one or more of the following elements to obtain binary alloys or alloys with more constituents: copper, iron, nickel, cobalt, tungsten, molybdenum, chromium, vanadium boron titanium manganese, zinc, silver, tin, thallium, bismuth, lead, cadmium, uranium, lithium, calcium, magnesium, aluminium, silicon, phosphorus, carbon, gold, platinum.

Inasmuch as concerns effecting the operation proper this operation consists in a general manner in bringing into contact the reacting materials for example in the cold, partly or wholly, in mixing them if desired and in melting them together for example in a crucible; it may be of interest for example when the temperature of fusion of the slag has been attained, to effect an agitation by any known means for example by

electrical or mechanical agitation, and the alloy or beryllium is finally allowed to separate from the slag formed.

For collecting thus the final product to be obtained as easily as possible without losses, and in the maximum state of purity, it has been ascertained that it is of interest to operate preferably in conditions such—due in particular to the careful choice of the reacting materials employed—that this final product (beryllium alloy or if desired metallic beryllium) is obtained in the form of a compact mass which separates by itself from the other products of the reaction forming in particular the slag.

This result may be obtained in particular by causing to act mixtures or alloys, of the reducing element or elements with the element or elements to be alloyed with the beryllium, which are such that they have a weight substantially different from that of the compound of beryllium treated, so that after admixture the alloy produced has likewise a weight substantially different from that of the slag which is formed and thus separates from it in the form of a compact product.

One may, for example, for this purpose cause a reducing alloy to act initially which is heavier than the compound of beryllium treated in the molten state and which gives rise to an alloy which is heavier finally than the slag formed which in general has a specific gravity which is lower if it is brought, for example by agitation of the said slag, into an advanced state of division.

Conversely when light alloys of beryllium are made the operation may be effected by employing reducing mixtures or alloys which form a slag clearly heavier than the product of the reaction; the alloy then collects above the slag.

According to the present invention it has been observed that the formation of beryllium alloys with desired contents is largely facilitated when the reducing element (metal or metalloid capable of reducing the beryllium compound) and the metal or metals (or possibly metalloids) to be alloyed with the beryllium are employed in the state of a mixture melting at a relatively low temperature and more particularly at a temperature below the melting point of its components. In the case of a metal to be alloyed with the beryllium there is advantageously employed a mixture or an alloy of the decomposing element and of this metal, associated in relative proportions which approach or correspond to the composition of the eutectic mixture.

The use of such a mixture with a low melting point with respect to its components, formed in general by metallic elements which are more electro-positive than beryllium with metallic elements less electro-positive than this latter, constitutes a very practical means for facilitating the exchange reaction which is effected in general between the more electro-positive element and the beryllium of the compound treated. It is only in certain cases by this means that the formation of alloys is rendered practically possible for a maximum yield. It is sufficient in these conditions to operate at a temperature which needs only be sufficient for the reacting materials and the beryllium alloy produced to be in the molten state.

In order to obtain more particularly light alloys of beryllium, for instance with aluminium, binary alloys may be used or alloys containing more than two metals which have the state of mixtures with a melting point which is low with respect to

the components and which react by double exchange upon the beryllium compounds. One may operate under such conditions that the temperature does not exceed in any case the melting point of the eutectic or eutectoid mixture formed by beryllium with the other metals to be alloyed with the beryllium.

There are obtained in particularly advantageous conditions the light alloys of beryllium by utilizing as reactive alloy a eutectic alloy with a low melting point; it happens that the beryllium during and in proportion to its formation passes into the state of the liquid alloy to be obtained and the melting point of this new alloy increases with the quantity of beryllium present, but whatever the high content of beryllium which it is desired to obtain in the final product, the beryllium set free alloys during and in proportion to its formation, and the temperature to be reached remains always very much lower than that which is necessary for the melting of pure beryllium (about 1285°).

In all cases the exchange reaction is effected at a temperature which is always relatively low and the lower, all other things being equal, the lower the melting point of the mixture employed for decomposing the beryllium compound with respect to the melting point of its components. The important thing is that the beryllium should be itself set free at a temperature which is always lower than the melting point of this metal but it does not pass into the solid state by reason of the fact that it finds for alloying with it during and in proportion as it is formed the other element or elements in the liquid state which form with it the alloy of beryllium to be obtained. In many cases the element of the alloy forms thus with beryllium an alloy constituting itself a eutectic alloy. The temperature of the reaction and duration of the operation are reduced to a particularly great extent when in order to ensure the double exchange reaction the decomposing element is employed precisely in the state of a eutectic alloy with the or one of the alloying elements.

The utilization of a eutectic can only conduce it is true to the formation of alloys of beryllium the contents of which only vary within relatively narrow limits. To obtain, however, all the possible range of the beryllium alloys the eutectic is caused to act in the presence of a desired supplementary quantity of alloying element. It is sufficient to add for this purpose the supplementary quantity calculated exactly in advance of the alloying metal of the eutectic or if desired of one or more alloying metals. In the normal conditions of the operation these additions of alloying element or elements do not exercise any influence upon the action of the decomposing eutectic alloy and in consequence one arrives at fusing without difficulty the alloying elements in desired proportions predetermined in the same operation with the alloy of beryllium formed by double exchange with the eutectic employed. The reaction will be effected more correctly if the decomposing eutectic alloy by the conditions of contact and/or temperature is more in condition to act upon the compound of beryllium to be decomposed before its eutectic character is substantially modified by intervention of the supplementary quantity of alloying element.

One may also effect the previous formation of the eutectic alloy in the body itself of the mixture which is subjected to the operation, by introducing in the free state a part of the metal which

should form the eutectic with the reacting decomposing element.

There are indicated in the following, various non-limiting examples corresponding to typical cases, of effecting the process according to the invention.

Example 1

Production of a beryllium aluminium alloy by means of magnesium and aluminium.

10 kgs of pure comminuted magnesium are introduced at the bottom of a crucible made of pure calcined alumina, or of alundum or of iron coated with a brasque of alumina. Upon this magnesium is charged 50 kgs of a mixture composed of two parts of normal beryllium and potassium double fluoride and a part of calcium fluoride previously molten, cooled and crushed, in which is distributed 2,3 kgs of aluminium in grains. The temperature is slowly raised up to 1150° C. When the molten mass is calm, it is poured into a mould suitably heated and is allowed to slowly cool. The product of the operation is a compact button of an alloy with 75% Be and 25% Al which floats upon the slag.

Example 2

Production of a beryllium nickel alloy by means of an alloy of magnesium and nickel.

At the bottom of a magnesite crucible or of a refractory crucible coated with magnesite is charged 11 kgs of an alloy Mg-Ni with 80% Mg and 20% Ni. Above it are alternatively placed in layers 50 kgs of normal beryllium and sodium double fluoride previously crushed, containing 6,8% of Be, and 20 kgs of magnesium fluoride. At the top of the charge is placed 7,8 kgs of pure nickel in portions. The whole is slowly heated up to about 1000° C. and the temperature is maintained constant for about half an hour, then hastily raised up to about 1150° C. When the molten mass is calm, it is poured into a mould properly heated. There is thus obtained a small mass of about 13 kgs of an alloy with 25% of Be and 75% of Ni which collects under the slag.

Example 3

Production of pure beryllium.

In a graphite crucible are charged at the bottom 0.5 kg of pure magnesium in portions, then 2 kgs of molten normal beryllium and sodium double fluoride containing 10% of beryllium and 1 kg of lithium fluoride which is also previously molten. The temperature is slowly raised up to 650° C. and maintained constant for a quarter of an hour. The temperature is then raised up to about 1300° C. while the crucible is allowed to oscillate. After cooling, there is obtained 185 gr. of beryllium in the form of a button which floats upon the slag.

In the claims, the expression "a metallic mass containing beryllium" is intended to include beryllium alloys as well as pure beryllium.

What I claim is:

1. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a quantity which practically corresponds stoichiometrically with the quantity of beryllium contained in said double fluoride, of a reducing element capable of reducing the beryllium fluoride to beryllium, and a halide of a metal of the group consisting of magnesium and the alkaline-earth metals and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

2. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together normal double fluoride of beryllium and sodium, a quantity which practically corresponds stoichiometrically with the quantity of the beryllium contained in said double fluoride of a reducing element capable of reducing the beryllium fluoride to beryllium, and a halide of a metal of the group consisting of magnesium and the alkaline-earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

3. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a mixture of a normal double fluoride of beryllium and an alkali metal and of beryllium fluoride practically anhydrous and free from oxide, a quantity which practically corresponds stoichiometrically with the quantity of the beryllium contained in said mixture, of a reducing element capable of reducing the beryllium fluoride to beryllium, and a halide of a metal of the group consisting of magnesium and the alkaline-earth metals, and in heating the whole until the reduction of the total beryllium fluoride is complete.

4. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a quantity which practically corresponds stoichiometrically with the quantity of beryllium contained in said double fluoride, of a metal belonging to the group consisting of the alkali metals, alkali earth metals, magnesium and aluminium, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

5. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a quantity which practically corresponds stoichiometrically with the quantity of beryllium contained in said double fluoride, of a metalloid belonging to the group consisting of the silicon and the boron, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

6. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a quantity which practically corresponds stoichiometrically with the quantity of the beryllium contained in said double fluoride, of an element capable of reducing the beryllium fluoride to beryllium, and an alkaline earth metal fluoride, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

7. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a quantity which practically corresponds stoichiometrically with the quantity of the beryllium contained in said double fluoride, of a reducing element capable of reducing the beryllium fluoride to beryllium and magnesium fluoride, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

8. Process for directly obtaining a metallic mass containing beryllium, which consists in

bringing together a normal double fluoride of beryllium and an alkali metal, a quantity which practically corresponds stoichiometrically with the quantity of the beryllium contained in said double fluoride, of a reducing element capable of reducing the beryllium fluoride to beryllium, at least one alloying element to be alloyed with the beryllium in quantity proportioned to the content to be obtained in the final alloy, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

9. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, an alloy of an element capable of reducing the beryllium fluoride to beryllium and at least one alloying element to be alloyed with the beryllium, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals, the reducing element being present in a quantity which practically corresponds stoichiometrically with the quantity of the beryllium contained in the double fluoride and the alloying element being present in a quantity proportioned to the content to be obtained in the final alloy, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

10. Process for directly obtaining a metallic mass containing beryllium, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, an element capable of reducing the beryllium fluoride to beryllium, a compound of an alloying element to be alloyed with the beryllium capable of being reduced by said reducing element, the reducing element being present in a quantity which practically corresponds stoichiometrically with the quantity of beryllium contained in the double fluoride and with the quantity of alloying element contained in said compound, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

11. Process for directly obtaining beryllium alloys, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a mixture of an element capable of reducing the beryllium fluoride to beryllium and of an alloying element to be alloyed with the beryllium, the said mixture having a composition such that it melts at low temperature with respect to its components and the reducing element being present in a quantity which substantially corresponds stoichiometrically with the quantity of beryllium contained in the double fluoride, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

12. Process for directly obtaining beryllium alloys, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, an alloy of an element capable of reducing the beryllium fluoride to beryllium and of at least one alloying element to be alloyed with the beryllium, the said alloy having a composition near to that of an eutectic alloy and the reducing element being present in a quantity which substantially corresponds stoichiometrically with the quantity of beryllium contained in the double fluoride, and a halide of a metal of the group

consisting of magnesium and the alkaline earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete.

13. Process as claimed in claim 12, in which a supplementary quantity of alloying element to be alloyed with the beryllium is added as such to the reaction mixture.

14. Process for directly obtaining beryllium alloys, which consists in bringing together a normal double fluoride of beryllium and an alkali metal, a mixture of an element capable of reducing the beryllium fluoride to beryllium and of an alloying element to be alloyed with the beryllium, the reducing element being present in a quantity which practically corresponds stoichiometrically with the quantity of beryllium contained in the double fluoride and the said mixture having a specific gravity widely different

from that of the beryllium and from that of the slag formed during the reaction, and a halide of a metal of the group consisting of magnesium and the alkaline earth metals, and in heating the whole until the reduction of the beryllium fluoride is substantially complete. 5

15. Process as claimed in claim 14, in which the mixture added to the double fluoride is such that it gives rise to a slag which is lighter finally than the beryllium alloy formed, so that the said alloy collects by itself in the form of a compact mass under the said slag. 10

16. Process as claimed in claim 14, in which the mixture added to the double fluoride is such that it gives rise to a slag which is heavier finally than the beryllium alloy formed, so that the said alloy collects by itself in the form of a compact mass floating on the said slag. 15

CARLO ADAMOLI.