Aug. 26, 1941. **J. H. DILLON** **2,254,170**

METHOD OF PRODUCING METALS HAVING RADIOACTIVITY

Filed Jan. 4, 1940 2 Sheets-Sheet 1

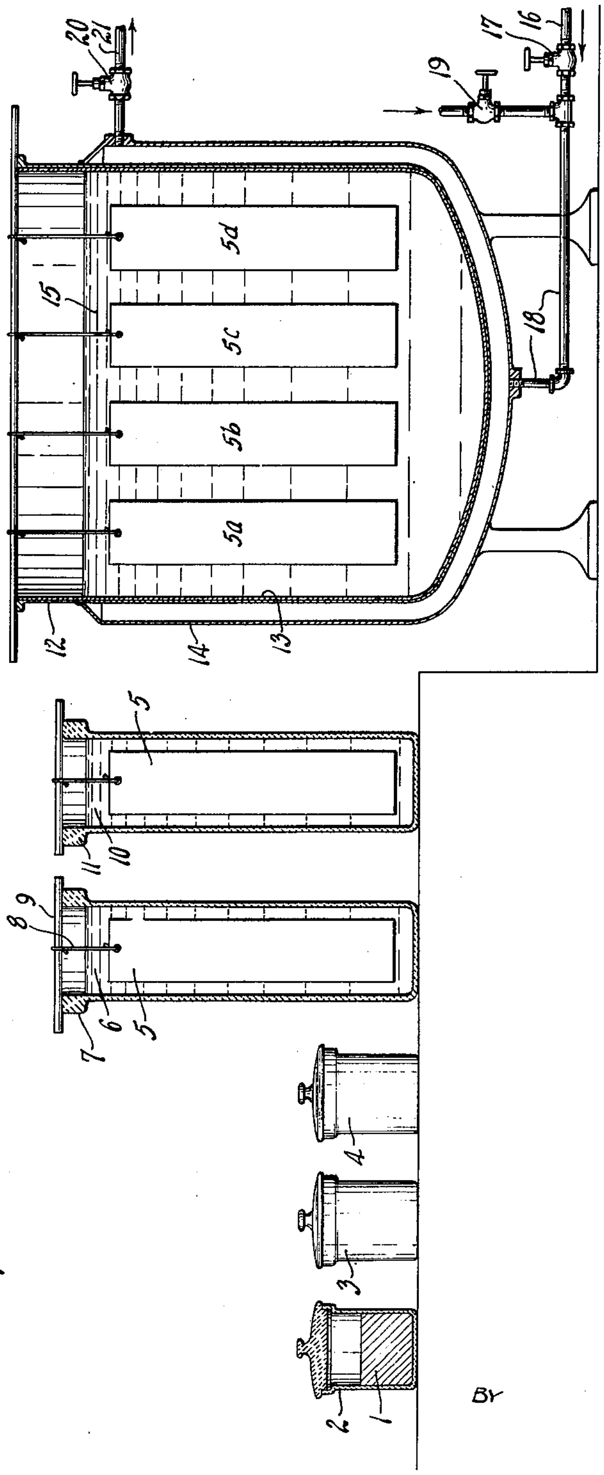

Fig. 1

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FIG. 2

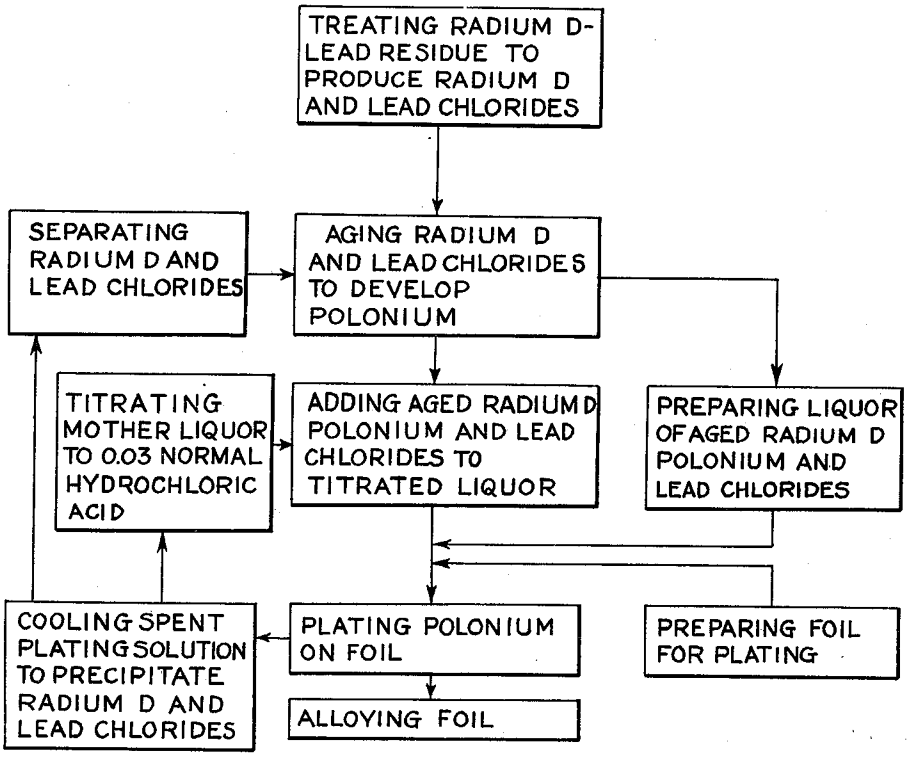
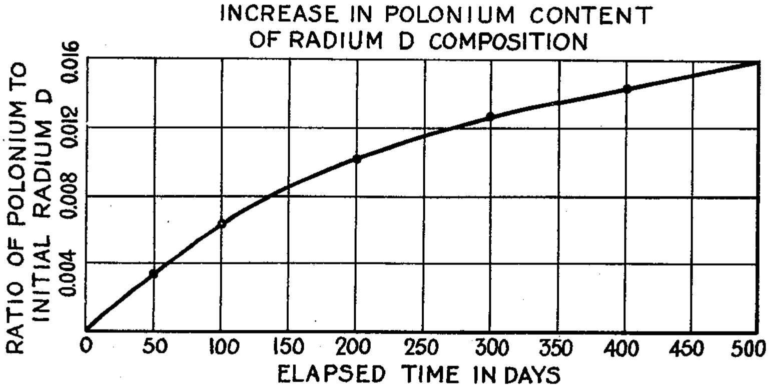


FIG. 3



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UNITED STATES PATENT OFFICE

2,254,170

METHOD OF PRODUCING METALS HAVING RADIOACTIVITY

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12 Claims. (Cl. 75—135)

This invention relates especially to polonium alloys and method of preparing same, but it also relates to an improved method of preparing other radioactive alloys and to a commercially practical method for the production of metallic polonium from its salts.

Heretofore, radioactive alloys have not been commercially produced. A commercial use of radioactive alloys has only recently been suggested, making the development of a commercially practical method for the preparation of such alloys desirable.

A primary object of the present invention is to provide a practical method of making a radioactive alloy, by the operation of which the amount of radioactive metal in the finished alloy may be readily controlled.

Another primary object is to provide a radioactive alloy resulting from said method.

Another object is to provide a method of making a polonium alloy.

Another object is to provide a method of making a radioactive alloy comprising nickel or, specifically, a nickel-polonium alloy.

Another object is to provide a radioactive alloy comprising a small but definite proportion of a radioactive metal.

A further object is to devise a commercially practical method of producing metallic polonium from its salts.

Further objects will be manifest from the specification, reference being had to the accompanying drawings, in which:

Figure 1 is an elevation, partly in section, of apparatus suitable for carrying out the preferred process of the present invention;

Figure 2 is a flow-sheet of one embodiment of the invention; and

Figure 3 is a diagrammatic representation of the development of polonium by aging of radium D.

Broadly, the present invention comprises plating a thin film of a radioactive metal onto the surface of another metal, preferably in foil form, to produce a plated metal. The plated metal is then melted with or without admixture of a diluting metal to form an alloy of the radioactive metal having a predetermined degree of radioactivity, or amount of a radioactive metal associated therewith. The diluting metal and the metal onto which the radioactive metal is plated are both usually non-radioactive, although not necessarily so.

In general, radioactive metals are very expensive because they are extracted with great difficulty from their ores, which are quite rare. However, it has been discovered that an alloy containing an exceedingly small proportion of a strongly radioactive metal possesses radioactive properties adequate for many purposes.

All radioactive materials give off one or more of three types of radiation called alpha, beta and gamma rays. The alpha rays, which are rapidly moving, doubly charged particles, are much more efficient for certain practical purposes, such as for ionizing gases, than either the beta rays (fast electrons) or gamma rays (electromagnetic radiation of extremely high frequency). Furthermore, the alpha rays are not dangerous to human beings, whereas gamma rays may be exceedingly harmful and require extreme safety precautions. The beta rays are also dangerous to some extent. Hence, it is quite apparent that a radioactive material emitting only alpha rays is much to be preferred for certain commercial purposes.

Table I shows the important relationships existing among members of the uranium-radium series of radioactive elements, including the types of rays given off. (See J. Am. Chem. Soc., 45, 872 (1923).) The half life value for radium D has been corrected to agree with more recent determinations. (See E. Walling, Zeitschrift für Physik, 87, 603 (1934).)

Table I

	Atomic		Half life	Radiation
	Wt.	No.		
Uranium I	238	92	4.67×10^{9} yrs	Alpha.
Uranium X_1	234	90	24.6 days	Beta.
Uranium X_2	234	91	1.15 min	Beta (gamma).
Uranium II	234	92	2×10^{6} yrs	Alpha.
Ionium	230	90	6.9×10^{4} yrs	Do.
Radium	226	88	1690 yrs	Alpha (beta and gamma).
Radon	222	86	3.85 days	Alpha.
Radium A	218	84	3.0 min	Do.
Radium B	214	82	26.8 min	Beta (gamma).
Radium C	214	83	19.5 min	Beta and gamma
Radium C′	214	84	10^{-6} sec	Alpha.
Radium D	210	82	22.3 yrs	(Beta and gamma).
Radium E	210	83	5.0 days	Beta.
Radium F of polonium.	210	84	136 days	Alpha (gamma).
Radium omega or lead.	206	82		

( ) means radiation is relatively feeble.

From the above table, it is seen that polonium, sometimes known as radium F, occurs among the end transformation products of radium. Radon tubes, which are no longer suited for their original therapeutic functions, constitute a convenient source of polonium. Radon tubes are small ampules of glass or gold originally charged with the gaseous radon evolved by radium salts. The radon changes into short-lived radium C, which gives off powerful gamma rays and makes the radon tubes medicinally useful. After a few days of usefulness by virtue of the gamma ray emission the radon tubes are medicinally "spent," since they contain practically no radon or radium C. They now contain mainly the relatively stable solid radium D, which exists as a minute deposit on the inner walls of the tubes. After several months of aging an appreciable amount of polonium is contained in the tubes, formed from the radium D at the rate indicated by Figure 3. Another source of greater commercial importance is the lead residue remaining after the extraction of radium from its ore. The lead residue is preferably treated to form the lead chloride salt. The resulting lead chloride contains all radioactive materials below radium C′ in the above table, being rich in radium D (an isotope of lead), which slowly changes into radium E, and containing appreciable radium F, or polonium. Radium E rapidly changes into polonium, as shown in the above table. Polonium is of especial interest because it is the only known radioactive metal emitting the desirable alpha rays almost exclusively and at a practical rate and giving rise to no other radioactive element emitting undesired beta or gamma rays. The immediate transformation product of polonium, radium omega, is an inactive isotope of ordinary lead. Thus no dangerous products develop from polonium, in contrast with radium, certain transformation products of the latter emitting strong beta and gamma radiation. Table I indicates that polonium emits feeble gamma rays in addition to strong alpha rays. It is well known that polonium emits only a few quanta of gamma rays for each million alpha rays. (See H. C. Webster, Chemical Abstracts, 32, 1565–6 (1938).) Practically speaking, therefore, polonium emits only alpha rays.

In selecting a radioactive metal for use in preparing a practical radioactive alloy the radiation activity of the metal must be considered. A radioactive element changes into another element according to an exponential law governed by the activity (number of rays per second) of the element. The selection of a metal of very low activity, such as uranium, would be unwise, because, even though it has the long half life (time required for one mass unit of the substance to be reduced to one-half mass unit) of approximately five billion years and emits only the desirable alpha rays, the activity of even the pure metal is too low to be of any practical value. On the other hand, radium A emits only alpha rays very copiously but has a half life of only three minutes. Polonium emits alpha rays at a rate in excess of 4500 times the alpha emission rate of pure radium, and has the reasonable half life of 136 days, which period of time is sufficient in many cases for the utilization of the strong alpha radiation of the substance. It is practicable to add sufficient polonium to an alloy such that the alloy has useful radioactivity for many purposes several years after it is produced. Only a very minute quantity of polonium need be present in an alloy in order to render same of practical value. For example, a spark plug electrode alloy initially containing as little as two one-hundred-millionths of one per cent of polonium has been found to be effective in ionizing the gas in the gap of the spark plug for an internal combustion engine, at the end of two years, when the polonium content of the alloy has fallen to less than one-billionth of one per cent.

Although polonium is the preferred radioactive metal for use in the present invention for the reasons given above, any other radioactive metal may be employed, so far as the present method is concerned. In addition to polonium certain other strongly radioactive metals emit alpha rays at effective rates and have sufficiently long half-life periods to render them especially useful in alloys. Such other strongly radioactive metals are radium, radiothorium, protoactinium, radioactinium and actinium X. It would be necessary to handle an alloy containing one of these metals with proper precautions in view of the beta and gamma radiation attending the desired alpha ray emission. A metal having an induced radioactivity is also contemplated for use in the present invention.

The method of the present invention is unique, in that it may be used to prepare a radioactive alloy comprising an exceedingly low but definite proportion of a radioactive metal. According to the present process the radioactive metal is first plated (by electrodeposition, electrochemical displacement, adsorption or vaporization) onto a base metal (in any convenient form such as, for example, plate, foil, wire, granules or powder). After determining the amount of plated radioactive metal, which amount can be relatively accurately predetermined, by any suitable measurement, as hereinafter described, the plated object is then melted with or without admixture of further base metal or other metal in order to produce the desired alloy or mixture of metals.

Unweighable quantities of the radioactive substance to be alloyed may be measured by a combination of an electroscope and an ionization chamber which has previously been calibrated against a known amount of a radioactive substance or an absolute measuring apparatus. An example of the latter type of apparatus is the so-called "Geiger" counter, such as was described by Rutherford and Geiger in The Proceedings of the Royal Society, volume 811A, page 141 (1908). Both of the above mentioned devices are usually responsive to alpha, beta and gamma rays to a greater or less extent, but may be made responsive only to alpha rays by selection of appropriate conditions, even though other rays are present. By the use of such modifications these devices may be used to determine accurately such an alpha ray emitting substance as polonium, even though radioactive substances which emit rays other than alpha are also present.

The following specific examples of methods for obtaining a plating of polonium and for making the polonium-base metal alloys are given for illustrative purposes only and are not to be construed as limiting the invention thereto:

Method A

A polonium solution containing a known radium D content was prepared by dissolving the solid contents of 10 crushed glass radon tubes in concentrated hydrochloric acid and diluting the solution to 0.27 normal in a one liter beaker. A strip 21 inches by 0.003 inch by 1 inch nickel foil (total surface area is 27,090 square millimeters) was etched the desired amount by treating it with concentrated nitric acid and then was copper-plated in a copper-sulfate solution (70 grams of copper sulfate per liter of water) for 25 minutes at 1 ampere and then for 5 minutes at 4 amperes. Next the copper-plated foil was suspended in the polonium-containing radium D solution to deposit polonium on the copper plated foil. Said solution was maintained at boiling temperature for 3 hours, evaporated water being replaced at frequent intervals. Thereupon, the polonium-plated foil was removed from the solution, washed and dried. By means of a Geiger counter the average polonium content of the foil plated by this method was found to be 1.42 micro-micrograms per square millimeter on measuring the alpha emission from several small square samples cut from various parts of the foil.

Method B

Live steam was forced through glass tubes into 28 gallons of water contained in a 32 gallon glass-lined tank. When the water had reached the boiling point, 120 cubic centimeters of concentrated hydrochloric acid and 8.4 pounds of polonium-containing lead chloride, such as is hereinbefore mentioned, were added to the bath.

Copper foils with an original thickness of 0.002 inch were prepared for receiving a plating of polonium by being etched to a thickness of about 0.0005 inch in nitric acid. These foils, having a total area of 162,000 square millimeters were then immersed in the boiling solution after all of the lead chloride had dissolved. The passage of steam through the solution was continued for about 5 hours and, in this instance, a polonium-plating was produced on the foils having an average polonium content of 3.24 micro-micrograms per square millimeter, when measured by a Geiger counter.

Method C

The preferred method for commercial plating of polonium is illustrated in part by Figures 1 and 2, and comprises, briefly, plating polonium from a lead solution containing same onto a suitable base metal, cooling the solution to precipitate lead chloride, separating the precipitated lead salt from the mother liquor, aging said salt to develop more polonium, and then forming a solution of the aged salt in the mother liquor from a previous plating operation and plating polonium as before. This method of plating makes possible the convenient production of the maximum quantity of polonium economically available from a given amount of a polonium-producing salt by means of relatively small and simple apparatus.

Referring to the method steps outlined in Figure 2 and the apparatus shown in Figure 1, the preferred commercial method contemplates aging a quantity 1 of lead chloride containing radium D in a suitable container 2, such as a covered five gallon glazed earthenware crock. The time of aging is dependent on economic considerations in view of the rate of increase in polonium content of the radium D, as shown in Figure 3. It may be seen that an aging period of several months is necessary in order for the polonium content to approach the maximum value. Since in a commercial process platings must be made frequently, several other containers, 3, 4, etc are provided for storing various batches of aging lead chloride containing radium D.

Prior to the plating operation a sheet of thin nickel foil 5 to be plated, which is about 8 inches by 36 inches by 0.003 inch, is suitably etched to produce a better plating surface thereon by being suspended for a short time in a nitric acid etching bath 6 that is contained in an earthenware crock 7. The foil 5 is positioned by a nickel wire 8 which is secured to a stainless steel rod 9 extending across the mouth of the crock 7. The etched foil is rinsed free of acid in water 10 contained in a container 11. The water rinse may be repeated, if desired, in order to remove the last traces of acid from the foil. After the water rinse, the foil 5 is ready for the plating operation which will be described hereinbelow.

In carrying out the plating operation with radioactive lead chloride which has not been previously used for plating polonium, preferably 75 pounds of the lead chloride are dissolved in 300 gallons of boiling 0.03 normal hydrochloric acid contained in a tank 12, which is lined with a chemically inert material, such as glass 13, which does not adsorb polonium from acid solution. The tank 12 is preferably equipped with a jacket 14 into which either steam or water may be introduced for heating or cooling the contents 15 of the tank; the steam entering the jacket through pipe 16, valve 17, and pipe 18, the condensate collecting in a suitable device such as a trap (not shown), which may suitably be located in pipe 18; or water entering through valve 19 and pipe 18 and leaving the jacket 14 through valve 20 and associated pipe 21.

Several prepared foils 5a, 5b, 5c, 5d, etc., are suspended in the radioactive lead chloride solution 15, and the solution is maintained at boiling temperature (approximately 100° C.) by admitting steam, suitably at 10 to 15 pounds gauge pressure, into the jacket 14 for a plating period of about 4 to 5 hours. Valve 17 and associated pipe 16 are connected to a suitable source (not shown) of steam, which is led to the jacket 14 by pipe 18. Condensate forming in the jacket 14 is allowed to drain through pipe 18 and valve 17 into a steam trap (not shown), as has been indicated hereinabove. Mechanical agitation of the solution, in addition to the agitation produced by boiling, is unnecessary. Practically all of the available polonium is plated onto the foils at the end of the plating period, but no measurable lead or radium D is present on the foils. The foils are then removed from the tank, rinsed with water and the rinsings added to the mother liquor in the tank. After the foils are dried their polonium content can be determined by means of a Geiger counter or ionization chamber equipment.

After removal of the foils from the plating tank, steam inlet valve 17 is closed and valves 19 and 20 are opened to allow cooling water to flow through valve 19 and pipe 18 into the jacket 14 and thence through the exit valve 20 and its associated pipe 21. The cooling water is allowed to circulate through jacket 14 until the temperature of the plating bath 15 has fallen preferably to about 20° C., which precipitates radium D-containing lead chloride crystals from the liquor. These crystals are then scooped from the bottom of tank 12 by use of a suitable means such as a wooden scoop. The separated wet crystals are placed in the container 2, pressed firmly therein, and drained, the drainings being returned to tank 12. The residual moist crystals weigh about 58 pounds. The container 2 is then dated and set aside for aging.

In a "subsequent plating operation," the mother liquor remaining from the first plating operation is titrated to determine its acidity, and sufficient acid or water is added to bring the acidity to the preferred value of 0.03 normal. The adjusted solution is heated to boiling and about 50 pounds of polonium-containing radioactive lead chloride are added thereto. The lead chloride may be taken either from a new supply of polonium-containing radioactive lead chloride or from properly aged precipitates of former platings, the precipitate from one plating batch drying to about 50 pounds after aging for several months. The remainder of the subsequent plating operation is identical with the corresponding portion of the first plating operation described above.

When two plating operations were carried out in accordance with the first plating procedure given in Method C wherein several foils are plated in one batch, the nickel foils to be plated having a total area of 64 square feet, two batches of plated foils were obtained showing total polonium contents of 21.6 and 18.8 micrograms.

A series of eight platings carried out in accordance with the "subsequent plating operation" described above produced eight batches of foils with a total polonium content of 140.3 micrograms, each group having a polonium content in the range of 15.1 to 22.6 micrograms.

No visible lead or radium D (isotope of lead) is observed on nickel foils plated in accordance with the preferred method, and no trace of lead is shown by spectroscopic tests.

Although other soluble radioactive lead salts, such as the acetate or bromide, may be employed in the plating process, the chloride is preferred. If other salts are used, the corresponding acids would replace the hydrochloric acid of the present preferred method. Although the acidity of approximately 0.03 normal is preferred when the chloride is used, satisfactory plating results have been obtained in the range of 0.08 normal to 0.001 normal. More highly acid plating baths with acidities ranging from 0.08 normal to higher than 1.0 normal may be used, but they have the disadvantages of decreased solubility for lead chloride and increased dissolving action on the foils, when the metal of the latter stands higher in the electromotive series than hydrogen. Of course, more than one plating tank may sometimes be an advantage. Thus it has been found that a single operator can conveniently prepare a second plating solution in a duplicate tank and etch a second set of foils while a plating operation is going on in the first plating tank. In other words, one operator can easily carry out one plating of the size indicated in Method C every day by the use of two plating tanks. The plating operation may be accelerated by inserting a suitable anode (not shown) in the tank **12**, making the foils cathodes, and passing a weak electric current through the solution **15**.

Before the polonium plated foils prepared in accordance with the invention can be used to the best advantage commercially, the polonium must be alloyed with other metals to form metal having a very small polonium content since only very small quantities of polinum need be present to give an alloy very desirable properties.

The alloyed metal of the invention may be made as follows:

Example 1

A 5 millimeter length of a nickel alloy wire, which had been copper-plated and then polonium-plated in accordance with Method A, was placed in the positive crater of a vertical carbon arc (D. C. operated ¾ inch carbons). The carbons were then pushed together and separated. A current of 20 amperes was allowed to flow for 2 to 5 seconds, at the end of which time the arc was extinguished with a high velocity stream of nitrogen. The resulting nickel-polonium alloy pellet was filed down to one-half its thickness and a high alpha particle emission from the filed surface was observed by means of the Geiger counter.

Example 2

A carbon crucible was made by drilling a 0.15 inch axial hole in a 0.37 inch diameter carbon electrode. A 5 inch by 0.010 inch by 0.062 inch nickel ribbon and a 2 inch length of 0.072 inch cylindrical nickel alloy wire were copper-plated and then polonium-plated in accordance with Method A. The ribbon was wrapped spirally about the plated section of the wire, and the whole was inserted in the crucible, the bottom of which was heated with a natural gas-oxygen torch. As the metal melted, the flame was moved higher on the crucible and, at the same time, the protruding unplated length of the wire was forced downward into the crucible. An ingot produced in this manner was found to have a high alpha particle emission.

Example 3

As a variation of Example 2, several short lengths of heavily polonium-plated nickel ribbons (0.010 inch by 0.062 inch) were piled into the form of a 0.06 inch by 0.06 inch bar. The melting procedure was the same as that of Example 2. A ingot (0.125 inch diameter) produced was filed down to a 0.094 inch diameter cylinder. The alpha emission from the cylindrical surface of the filed ingot, which was made in accordance with this procedure, indicated that the polonium concentration was about 270 micro-micrograms per cubic millimeter of the nickel alloy, or about one-three hundred thousandths of one per cent.

Example 4

In this instance, the alloying efficiency of the polonium is to be measured so that measured quantities of polonium and alloying metal must be used. Thus polonium-plated foil having 27,090 square millimeters of surface containing 1.42 micro-micrograms of polonium per square millimeter or a total of 0.0384 micrograms of polonium was melted with a calculated amount of nickel to produce 3,620 cubic millimeters of a nickel-polonium alloy. The melting operation was carried out in a small magnesium oxide crucible with an internal diameter of ¾ inch which was fitted into a 2 inch internal diameter graphite crucible that was mounted in an electric induction furnace. In the melting operation, the required amount of nickel was first heated and melted in the magnesium oxide crucible and then the polonium-plated foil (rolled tightly into a cylinder) was added to the melt. High frequency current was then allowed to pass through the melt for 20 seconds in order to insure thorough mixing of the metals after which the current was cut off and the crucible removed from the furnace. An ingot about ¾ inch by ½ inch was obtained when the solidified alloy was removed from the magnesium oxide crucible.

Then the ingot was hand-forged and swaged to form a cylinder of ¼ inch diameter and approximately 4 inches in length. The cylinder was next drawn down to 0.072 inch diameter in accordance with the usual practice. The alpha emission of the finished wire made in accordance with this example was measured by means of a Geiger counter and the polonium content of the wire was determined to be 8.0 micro-micrograms per cubic millimeter of alloy. Since 10.6 micro-micrograms of polonium were added for each cubic millimeter of nickel-polonium alloy made, the alloying efficiency for the polonium in this case was 75%.

Example 5

Two groups of plated foils, having a combined polonium content of 40.4 micrograms, were prepared according to the first specific procedure described in Method C. Applying the procedure of Example 4 (larger equipment being used) the foils were added to sufficient molten nickel to produce 310 pounds of alloy. The input of polonium was equal to 0.13 microgram per pound of alloy while the polonium per pound of alloy was measured and found to be 0.11 microgram per pound. It results that the alloying efficiency was 85 per cent.

Example 6

Foils containing a total of 140.3 micrograms of polonium were prepared according to the "subsequent plating procedure" of Method C. Applying the procedure of Example 5, the foils were added to sufficient molten alloy high in nickel content to produce 1600 pounds of alloy. Here the input of polonium corresponded to 0.09 microgram per pound of alloy while the polonium per pound of alloy was found to be 0.08 microgram per pound. The alloying efficiency in this case was, therefore, 89 per cent.

The above examples show the formation of alloys containing polonium in the range of approximately one-one hundred millionth of one per cent to one-one hundred thousandths of one per cent. Obviously an alloy containing even less polonium, such as one billionth of one per cent or less, can be prepared by melting the polonium-plated metal with an even larger proportion of the other metal. Likewise, an alloy containing a larger percentage of polonium than 0.00001 can be produced by melting a plated foil containing a larger proportion of polonium than shown by the foils described above. Although the examples show the preferred use of nickel or a nickel alloy as the non-radioactive component of the radioactive alloys produced, a similar non-radioactive metal, such as cobalt, may be used instead to produce similar alloys, no matter which radioactive metal is chosen for the alloy. Of course, any other suitable substantially non-radioactive metal may also be substituted for nickel in the method of the present invention.

Any workable method of forming a deposit, plating or coating of polonium on a base metal is satisfactory for the purposes of the present invention. Thus, polonium may be plated by electrochemical displacement onto any other metal having a higher electrode potential than polonium (e. g., silver, copper, lead, nickel, cobalt and aluminum), although for practical reasons metals less electropositive than aluminum are preferred. Polonium may also be plated onto any suitable metal electrode by electrodeposition from a solution containing polonium. A coating of polonium may also be formed on a metal such as silver, gold or platinum by adsorption from a solution comprising polonium. Furthermore, polonium may be vaporized or distilled onto another metal, preferably at a sub-atmospheric pressure. These methods apply also to the production of platings of other radio-active metals.

In addition to spent radon tubes and the lead residues attending the preparation of radium, other compositions containing polonium are contemplated for use in the present method. Some other commercial compositions or naturally occurring compositions, which contain appreciable proportions of polonium in the absence of material proportions of radium D or lead, are also suitable for use in obtaining polonium for preparing radioactive metals or alloys according to the present invention.

Although it is thought that the mixtures of metals herein described as alloys are properly so designated, it has not been found possible to prove that a true alloy is always produced by the practice of this invention. Therefore, it is to be understood in the specification and appended claims that "alloy" means any substantial mixture of two or more metals, such as the product of the present method. Although it is thought that the radioactive alloy produced by the method of the present invention is a substantially uniform dispersion of the radioactive metal throughout the other components of the alloy, it is possible that some of the radioactive metal is oxidized during the alloying process, so that the alloy may contain a substantially uniform dispersion of the oxidized radioactive metal.

Various modifications may be made without departing from the nature and spirit of the invention as defined in the appended claims.

What is claimed is:

1. A method of separating polonium from a material comprising polonium and radium D, which comprises forming a hot slightly acid solution of material of the above class, immersing a piece of metal in the solution, depositing the polonium on the surface of the metal, cooling the solution to precipitate most of the polonium-depleted material therefrom, separating the precipitate from the mother liquor, aging the precipitate until more polonium is formed, and then dissolving the aged precipitate in the hot mother liquor from a former depositing operation to provide a solution capable of depositing a further quantity of polonium onto a suitable base metal.

2. A method of preparing a radioactive alloy, which comprises depositing a radioactive metal on the surface of a metal to form a plated metal, and subsequently melting the plated metal in the presence of a quantity of molten metal.

3. A method of preparing a radioactive alloy, which comprises depositing a radioactive metal on the surface of a metal to form a plated metal, and adding the plated metal to molten metal.

4. A method of preparing a radioactive alloy, which comprises forming a deposit of polonium on a metal from a hot slightly acid solution comprising polonium and radium D to form a plated metal, and adding the plated metal to a calculated amount of a molten alloying metal.

5. A method of preparing a radioactive alloy, which comprises depositing a radioactive metal on the surface of a metal to form a plated metal,

melting the plated metal, and passing a high frequency electric current therethrough.

6. A method of preparing a radioactive alloy, which comprises depositing polonium on the surface of a metal to form a plated metal, melting the plated metal, and passing a high frequency electric current therethrough.

7. A method of preparing a polonium alloy, which comprises forming a plated foil by depositing polonium on the surface of a metal foil consisting substantially of a material selected from the group consisting of copper nickel and copper-plated nickel by immersing the foil in a hot solution comprising polonium ions, melting the plated foil in the presence of a quantity of molten metal comprising mainly nickel, and passing a high frequency electric current through the mass of metal.

8. That method of preparing a radioactive alloy comprising etching a sheet of a suitable metal foil, immersing the etched metal foil in a slightly acid solution containing a radioactive metal, boiling the solution to deposit radioactive material upon the metal foil, and thereafter melting the metal foil which has radioactive material plated thereon to form a radioactive metal alloy.

9. That method of preparing a radioactive alloy comprising preparing a sheet of a suitable metal foil, immersing the prepared metal foil in a solution containing a radioactive material, boiling the solution to deposit radioactive material upon the metal foil, and thereafter adding the metal foil which has radioactive material plated thereon to a quantity of molten metal to form a radioactive metal alloy.

10. That method of preparing a polonium-containing metal comprising etching a sheet of a suitable metal foil, immersing the etched metal foil in a polonium-containing solution, boiling the solution to deposit polonium upon the metal foil, and thereafter melting the metal foil which has polonium plated thereon to form polonium-containing metal.

11. That method of preparing a radioactive metallic wire comprising preparing a sheet of a suitable metal foil, immersing the prepared metal foil in a solution containing a radioactive material, depositing radioactive material upon the metal foil, adding the metal foil which has radioactive material plated thereon to a quantity of molten metal to form a metal exhibiting radioactivity, and thereafter drawing the said metal exhibiting radioactivity down to form a radioactive metallic wire.

12. That method of preparing a metal having radioactivity comprising preparing a sheet of a suitable metal foil, immersing the prepared metal foil in a solution containing a radioactive material, passing a weak electric current through the solution and the metal foil to deposit radioactive material on the metal foil, and thereafter adding the metal foil which has radioactive material plated thereon to a quantity of molten metal to form a metal exhibiting radioactivity uniformly throughout its mass.

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