

UNITED STATES PATENT OFFICE

2,579,243

METHOD FOR THE PRODUCTION OF RADIOACTIVE ISOTOPES

Allen F. Reid, New York, N. Y., assignor to the
United States of America as represented by the
United States Atomic Energy Commission

No Drawing. Application April 13, 1945,
Serial No. 588,257

3 Claims. (Cl. 204—154)

1

This invention relates to the production of radioactive isotopes by bombardment of an appropriate target with high-velocity, sub-atomic particles, and particularly to an improved target for this purpose.

Substances containing radioactive isotopes have recently been in demand for a variety of purposes such as for tracers in pathological studies of the utilization by the human body of those substances in their ordinary, inactive form. Such active substances may be prepared by bombarding a suitable target with high-velocity, sub-atomic particles such as alpha particles, protons, neutrons and the like which are capable of causing a nuclear reaction in an element of the target, to produce the desired radioactive isotope. Frequently, the particles may be generated by a cyclotron and in such cases the target may be inserted into the cyclotron casing where the intensity and energy of the beam of particles are relatively high or the beam may be brought out of the cyclotron through a suitable window or opening and caused to impinge on the target at a point outside the cyclotron casing. In most cases greater efficiency can be obtained by inserting the target into the cyclotron and in some cases the desired nuclear reaction will not proceed at all or will proceed only to a negligible extent unless the target is so inserted.

The character of the beam of high-velocity, sub-atomic particles is such that it tends to heat the target to very high temperatures which may fuse or vaporize one or more components of the target and the physical impact of the bombarding particles tends to cause mechanical disintegration of the target. In order to obtain desirable yields of radioactive materials, the target should be sufficiently refractory to withstand the high temperatures generated by the incident beam without melting, vaporizing, or decomposing chemically and should be sufficiently coherent to withstand the impact of the bombarding particles without mechanical disintegration.

It is apparent that mechanical disintegration of the target should be avoided if high yields of the radioelement are to be obtained. When such disintegration occurs the target material may be scattered by impact of the incident particles. Furthermore, since atoms of the radioactive material are formed by collision of the bombarding particles with atoms of the target element, it is evident that when the target material lacks coherence the probability that an atom of the radioactive material will be scattered is relatively greater than the probability that an atom of the target element will be scattered.

2

For the purpose of reducing undesired temperature effects it has been the common practice to prepare targets comprising a relatively thin layer of the material to be bombarded on a heat-conductive base, and to cool the base and associated layer with a rapidly flowing stream of cooling water. However, the energy of the incident beam is so great that even when an attempt is made to cool the target in this manner, the target temperature rises to values sufficient to vaporize many elements and compounds.

Targets have been prepared by depositing as by electroplating on a suitable metallic base, a relatively thin layer of a metal which is to serve as the source of the desired radioactive isotope. The electroplate metal may be the same element as the radioactive isotope produced or it may be a different element. However, owing to the severe conditions to which the target is subjected during bombardment, i. e., the high energy level and intensity of the beam, such a target is generally unsuitable where the deposited metal which is to serve as the source of the desired radioactive isotope belongs to the alkali metal group or alkaline earth metal group, since these metals are volatile and highly reactive with air to form oxides which rapidly undergo mechanical disintegration when subjected to a stream of high-velocity, sub-atomic particles.

According to the present invention, it has been found that metaborates and boron oxide have highly desirable characteristics for use in the surface layer of the target in that they do not undergo melting, vaporization or chemical decomposition and are highly cohesive so that they do not experience mechanical disintegration when struck by the bombarding particles. More particularly, it has been found that suitable targets in which the source of the desired radioactive isotope is lithium, potassium, sodium, calcium, barium, strontium and cesium may be made using the metaborate of the radioactive isotope-producing element, as the surface layer.

It is therefore one of the objects of the invention to prepare a target having a surface layer of a compound serving as the source of a desired radioactive isotope, which is capable of withstanding bombardment with high velocity, sub-atomic particles.

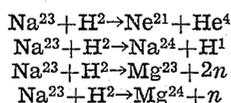
Other objects of the invention are to prepare an improved target having a surface layer of a metal compound in which the metal element belongs to the alkali metal group or the alkaline earth metal group; and to provide a target in which a metaborate is mixed with another substance of the surface layer to improve the char-

acteristics of the other substance for bombardment.

Further objects are to provide a method for producing radioactive isotopes by using a suitable metaborate target and to provide a method for making said target.

One particularly important radioactive isotope in pathological studies is Na^{24} which is frequently used in the form of sodium chloride to study blood circulation in the body. The invention will be described with particular reference to the production of Na^{24} by bombarding a target having a surface layer of sodium metaborate with deuterons in a cyclotron.

When a substance containing ordinary sodium is bombarded with deuterons, the reactions are as follows:



The reaction products includes Na^{24} and Mg^{23} which is also radioactive. The boron and oxygen isotopes of the metaborate also undergo nuclear reactions with the deuterons to produce in some instances radioactive isotopes. However, since it is possible by means of rather simple chemical treatment of the bombarded material to segregate Na^{24} from the other radioactive isotopes, sodium metaborate is a suitable material for the production of sodium chloride in which the only radioactive element present is Na^{24} .

The metaborate is preferably used in the form of a relatively thin layer on a heat conductive base such as copper. The optimum thickness of the layer is largely determined by the characteristics of the bombarding particles and the layer should be of such a thickness as to utilize these particles with maximum effectiveness. As the bombarding particles penetrate the target layer their energies decrease, and the reduction of energy is a function of the distance the particles penetrate. On the one hand the layer of target material should be sufficiently thick to fully utilize the energy of the bombarding particles, i. e. thick enough to reduce the energy of the bombarding particles to the threshold energy for the desired nuclear reaction. On the other hand the layer should be made relatively thin so that it may be more readily cooled by the cooling water brought into contact with the heat-conductive base and so that the specific activity produced will be high. If the layer is made too thick, the inner portion of the target element serves no useful purpose and acts in effect as a diluent to reduce the activity produced per unit weight of material.

A copper plate about 1" square and $\frac{1}{16}$ " thick is prepared as a heat-conductive base for the layer of target material by cutting a series of V-shaped ridges or notches in one surface of the plate. The sides of the ridges form an angle of about 45° with the surface of the plate and approximately 50 ridges are used.

On the ridged surface of the plate as thus prepared there is spread a thin layer of sodium metaborate and the base and metaborate layer are heated until the metaborate fuses. The quantity of material used is such as to give a metaborate layer of approximately 7 mg. per square cm. of copper plate. The metaborate fuses to form a coherent mass which adheres strongly to the copper base.

The copper base with the target layer as thus

formed is soldered to a conventional probe provided with cooling water inlet and outlet conduits for cooling the base and associated layer and the probe is inserted in the cyclotron. The target layer is preferably so positioned as to form a relatively small angle with the plane of the beam, i. e., the angle of incidence of the beam should desirably be of the order of 80°. Furthermore the target should be arranged lengthwise with respect to the beam so that the ridges are approximately parallel to the beam and a maximum surface of the target material is exposed to the beam.

The target is then exposed to a beam of 8 m. e. v. deuterons having an intensity of about 700 watts for a period of time sufficient to produce the desired activity of radioactive sodium. It has been found that an activity of about 100 millicuries per hour of exposure may be obtained.

After the target has been bombarded for the desired period of time, the target is digested with water until the digesting liquid has as much radioactivity as desired. To produce a high concentration of radioactive sodium only a small portion of the target is dissolved since the most concentrated material is at the surface and will dissolve first. If products of weaker radioactivity are desired, a large amount of the target is dissolved or all of it. The solution, which is basic at this stage, is filtered. The filtrate is made strongly acidic with HCl and methyl alcohol is added and the mixture is evaporated to dryness. This latter sequence is repeated a number of times and then on the final evaporation to dryness the product is pure sodium chloride in which a proportion of the sodium atoms is radioactive Na^{24} .

While the invention has been described with particular reference to the production of the radioactive isotope of sodium from sodium metaborate by bombardment with deuterons in a cyclotron, it is understood that this does not constitute a limitation. For example, other types of particles such as alpha particles and neutrons may be used alternatively to carry out other nuclear reactions. Likewise the metaborate need not be sodium metaborate but may be a metaborate of another alkali metal or of an alkaline earth metal such as lithium, sodium, potassium, calcium, barium, strontium, and cesium or of other metals, e. g., vanadium metaborate and columbium metaborate. Boron oxide which may be considered a metaborate of boron is also useful as a target material. It is also contemplated that a metaborate may be mixed with another compound which is to be the source of the radioactive isotope desired, to impart to the latter compound the resistance to bombardment conditions which is a characteristic of the metaborate grouping. For example it has been found that a pure orthoborate is unsuited as target material but may be used when mixed with a proportion of a metaborate. It is also within the scope of the invention to use a mixture of metaborates such as sodium metaborate and potassium metaborate.

Since many embodiments might be made of the above-described invention and since many changes might be made in the embodiment described, it is to be understood that the foregoing description is to be interpreted as illustrative only and not in a limiting sense.

I claim:

1. A method of producing radioactive isotopes which may be derived from elements of the metaborates of the group of the alkali metals

5

and the alkaline earth metals, which comprises bombarding a metaborate of a suitable element of said group with a stream of high-velocity, sub-atomic particles.

2. A method of producing radioactive isotopes which may be derived from the metaborates of the group of the alkali metals and the alkaline earth metals, which comprises bombarding a target having a layer of a metaborate of an element of said group bonded to a heat-conductive base, with a stream of high-velocity, sub-atomic particles.

3. A method of producing the radioactive isotope of sodium which comprises bombarding a target having a layer of sodium metaborate bonded to a heat-conductive base, with a stream of high-velocity, sub-atomic particles.

ALLEN F. REID.

6

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
Re. 22,011	Kinzie et al.	Jan. 20, 1942
1,271,320	Houskeeper	July 2, 1918
1,733,744	Marden et al.	Oct. 29, 1929
1,835,113	Iredell	Dec. 8, 1931
2,146,093	Ritchie et al.	Feb. 7, 1939
2,206,634	Fermi et al.	July 2, 1940
2,303,658	Porter	Dec. 1, 1942
2,316,595	Kallmann	Apr. 13, 1943

OTHER REFERENCES

Crane et al., Phy. Rev. 45, 497-8 (1934).