April 18, 1950

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2,504,585

CYCLOTRON TARGET

Filed Jan. 26, 1945

Fig. 1.

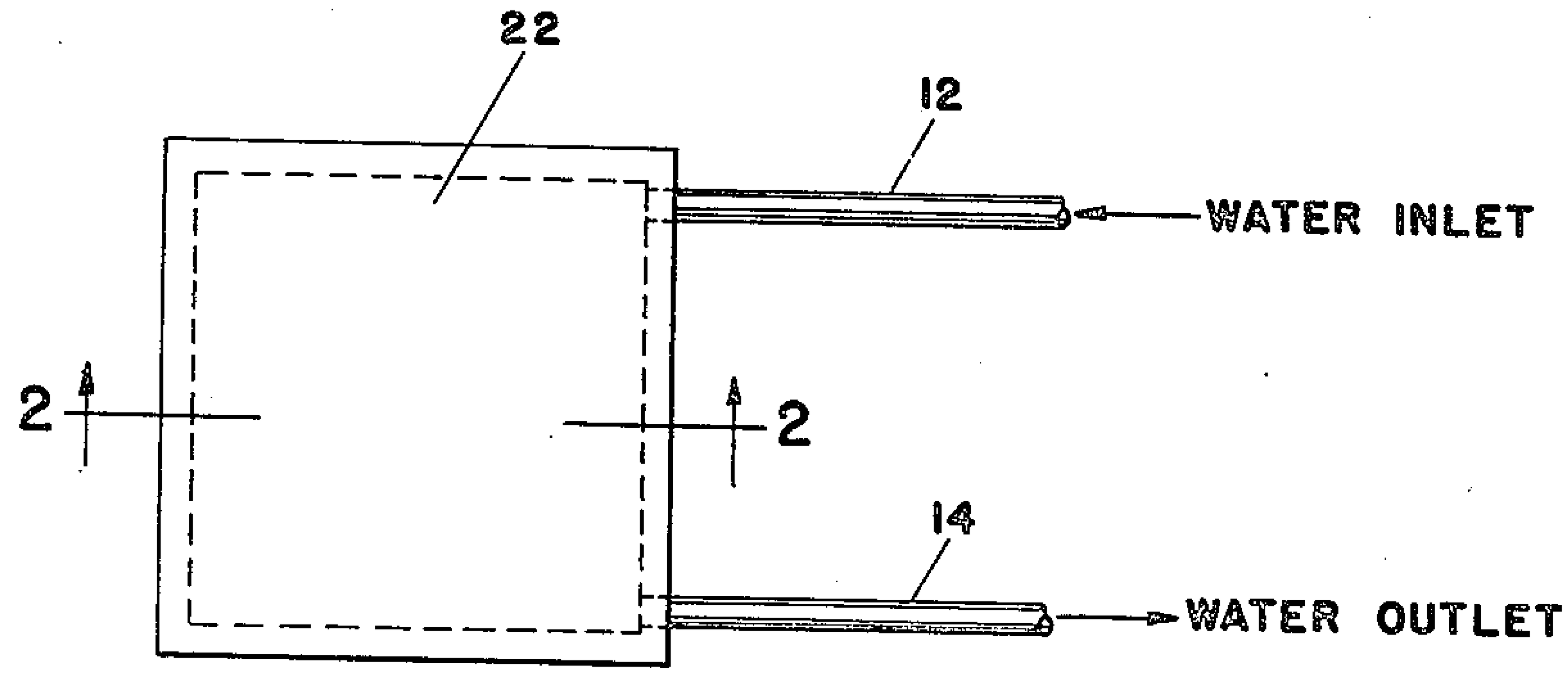
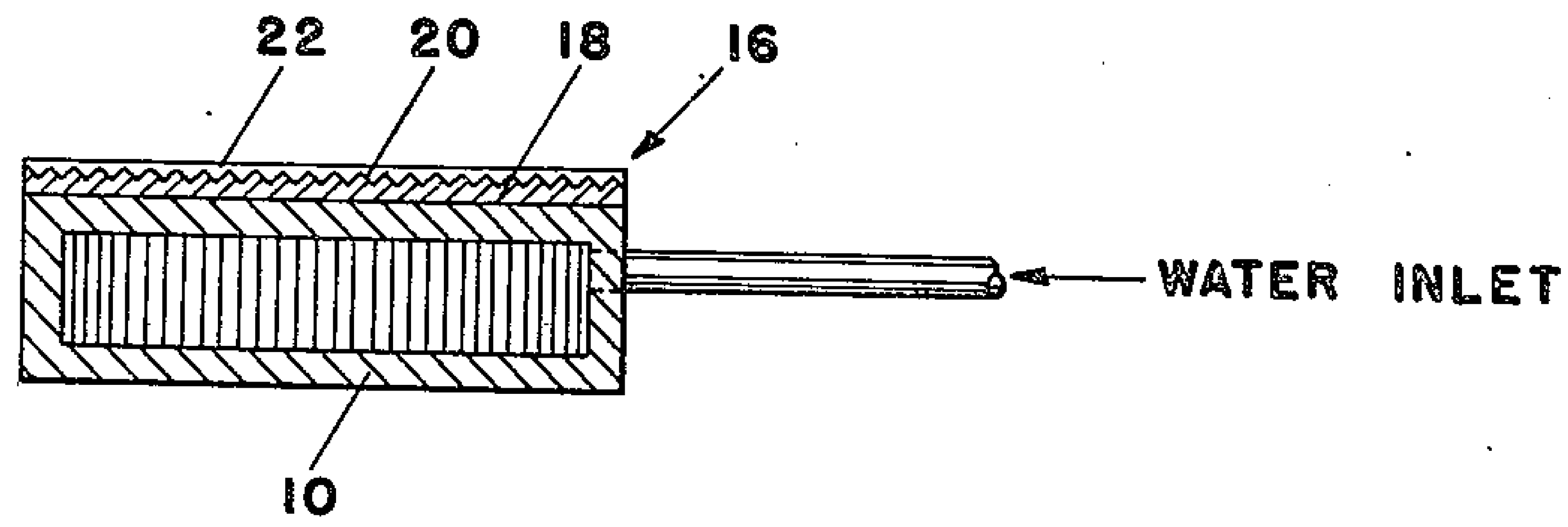


Fig. 2.



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Patented Apr. 18, 1950 **2,504,585**

UNITED STATES PATENT OFFICE

2,504,585

CYCLOTRON TARGET

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Application January 26, 1945, Serial No. 574,807

7 Claims. (Cl. 117—129)

1

This invention relates to the production of radioactive materials by bombardment with high-velocity sub-atomic particles and more particularly to a method of preparing radioelements such as, for example, radioiodine by bombardment with a stream of deuterons in a cyclotron. The invention further relates to an improved target for use in such a method.

In recent years there has been considerable interest in the production of radioactive isotopes of various elements by bombardment of a suitable target placed in a stream of high-velocity sub-atomic particles produced, for example, by a cyclotron. Radioelements may be prepared by bombardment with particles such as deuterons or protons of a target composed of or comprising an element suitably selected to cause a nuclear reaction producing the desired radioactive isotope. The target element may be the same element as the radioisotope produced or may be a different element. In cases where the bombarding particles are produced by a cyclotron, 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.

Due to the severe conditions existing within the cyclotron during bombardment, i. e. the high energy level and intensity of the beam, the preparation of suitable targets has presented a serious problem, particularly in those cases where unusually high energies are required to cause the nuclear reaction producing the desired radioelement to proceed, and bombardment within the cyclotron is mandatory if reasonably efficient conversions are to be obtained.

The character of the beam 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 in such cases, the target should be sufficiently refractory to withstand the high temperatures generated by the incident beam without melting, vaporizing, or decomposing chemically and should

2

be sufficiently coherent to withstand the impact of the bombarding particles without mechanical disintegration.

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 temperatures rises to values sufficient to vaporize many elements and compounds.

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.

One of the radioisotopes that is of considerable interest is radioiodine (I^{131}) which has a half life of 8 days. This isotope of iodine may be used for a variety of purposes including, for example, its use as a "tracer" in pathological studies of the utilization of iodine by the human body. In preparing radioiodine it has been customary to bombard a target comprising an alloy of copper, cobalt and tellurium containing somewhat more than 50% tellurium with a stream of high-velocity deuterons in a cyclotron. Several nuclear reactions occur which may be represented by the following equations, the first reaction being the predominant one.

$$Te^{130}+H^2=I^{131}+n$$
$$Te^{130}+H^2=I^{130}+2n$$
$$Te^{130}+H^2=H^1+Te^{131}=I^{131}+\beta$$

A relatively high energy beam is required to cause these reactions to proceed satisfactorily and therefore the reactions are desirably carried out within the cyclotron.

The conventional copper-cobalt-tellurium target has the advantage that it contains a relatively large proportion of tellurium. However its physical character is such that a considerable portion of the activity in the target is either vaporized or otherwise dissipated during exposure of the target to the cyclotron beam and therefore the yield of radioiodine using such a target is relatively low.

It is an object of the present invention to provide an improved target for use in the production of radioiodine by bombardment of tellurium with high-velocity sub-atomic particles.

It is a further object of the invention to provide a target containing tellurium that is relatively refractory to the temperatures generated during bombardment by a stream of high energy deuterons and that is sufficiently coherent to prevent disintegration by impact of the deuterons.

It is still another object of the invention to provide a method of making such a target.

It is a still further object of the invention to provide a method of producing radioiodine and/or other radioelements by bombardment of a target comprising thallous tellurite.

Other objects of the invention will be in part obvious and in part pointed out hereinafter.

In one of its broader aspects the present invention comprises an improved target for use in the production of radioisotopes of iodine and/or other elements by bombardment with high-velocity sub-atomic particles such as deuterons, the target comprising a heat-conductive base having a relatively thin, adherent layer of thallium tellurite thereon. It has been found that thallous tellurite when properly applied to a suitable supporting base is unusually resistant to the conditions existing within a cyclotron during bombardment and that a relatively high yield of radioiodine may be obtained when this material is used as a target.

The thallous tellurite is preferably used in the form of a relatively thin, vitreous layer on a heat-conducting 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. This point is particularly important where the target element is the same element as the radioisotope resulting from the nuclear reaction. Where the radioisotope produced is a different element from the target element it may usually be separated therefrom and concentrated by chemical means.

The target as described above is preferably mounted on a conventional water-cooled probe. The particular structure of the probe forms no part of the present invention and any of various known probes may be used such as, for example, those described by Livingston, "Journal of Applied Physics," volume 15, Number 2, pages 128 to 147. In order to point out more fully the nature of the present invention the following specific example is given of a preferred method of making the target of the present invention and of a suitable mounting for the target. In this specific example reference will be made to the accompanying drawing wherein Figure 1 is a top plan view of a target and probe and Figure 2 is a vertical section taken on the line 2—2 of Figure 1.

Referring to the drawing the probe comprises a hollow chamber 10 made of a suitable heat-conductive material such as copper. The interior of chamber 10 is supplied with water by an inlet tube 12 and water is withdrawn from the chamber 10 through an outlet tube 14 in such manner that the walls of the chamber 10 are continuously cooled.

The target proper, generally designated 16, is affixed to the upper surface of the chamber 10 and comprises a thin copper plate 18 which may be, for example, 1 inch square and $\frac{1}{16}$ inch thick. The upper surface of plate 18 is provided with a series of V-shaped ridges or notches 20. The sides of the ridges 20 form an angle of about 45° with the surface of the plate and approximately 50 ridges are used.

The plate 18 forms a heat-conductive base for a layer of target material 22 which is preferably applied to the base 18 before the base is secured to the probe chamber 10. Application of the target material 22 to the base 18 is effected by spreading a relatively thin layer of thallous tellurate ($TlTeO_4$) on the ridged surface of the base and then heating the base and tellurate layer to a temperature of about 800° C. to convert the tellurate into a tellurite ($TlTeO_3$). The quantity of material used is such as to give a tellurite layer of approximately 2.0 milligrams per square centimeter of copper plate. The tellurite fuses to form a coherent vitreous mass that adheres strongly to the copper base. The target as thus formed is then affixed to the top of probe chamber 10 in any suitable manner such as by soldering and the probe and associated target are 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 9.5 M. E. V. deuterons having an intensity of about one kilowatt for a period of time sufficient to produce the desired activity of radioiodine. It has been found that an activity of about 0.05 millicurie per hour of exposure may be obtained. The activity obtained under similar conditions using a copper-cobalt-tellurium target varies somewhat with the characteristics of the particular cyclotron used but in general is of the order of one tenth to one half of the activity obtained with the target of the present invention.

It is to be understood that the foregoing description is illustrative only and that various changes might be made therein and in the scope of application of the present invention. Thus the target described above may be bombarded with other types of particles such as alpha particles and protons and a variety of nuclear reactions may be carried out. By an appropriate choice of bombarding particles and beam energies the target of the present invention may be used in the production of radioisotopes of elements such as antimony, xenon, mercury, thallium, lead and bismuth. In general the present target may be used in conjunction with known nuclear reactions to produce radioisotopes of elements having the atomic numbers 51, 52, 53, 54, 80, 81, 82 and 83.

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 target for use in the production of radioisotopes of elements selected from the group having the atomic numbers 51 through 54 and 80 through 83 by bombardment with high-velocity sub-atomic particles, said target comprising a heat-conductive base having a relatively thin, adherent layer of a thallium tellurite thereon.

2. A target for use in the production of radioiodine by bombardment of tellurium with high-velocity sub-atomic particles, said target comprising a heat-conductive base having a relatively thin, adherent layer of thallous tellurite thereon.

3. A target for use in the production of radioiodine by bombardment of tellurium with high-velocity deuterons, said target comprising a copper base having a relatively thin, vitreous layer of thallous tellurite thereon.

4. A target for use in the production of radioiodine by bombardment of tellurium with high-velocity deuterons, said target comprising a copper base having a ridged surface, said ridged surface having thereon a vitreous layer of thallous tellurite of such thickness as to reduce the energy of said deuterons to a value just below the threshold energy for production of radioiodine from tellurium.

5. A method of making a target for bombardment with high-velocity sub-atomic particles comprising the steps of coating a heat-conductive base with a relatively thin layer of thallous tellurate and heating said base and tellurate layer to convert said tellurate into a firmly adherent, vitreous layer of thallous tellurite.

6. A method of making a target for bombardment with high-velocity sub-atomic particles comprising the steps of coating a heat-conductive base with a relatively thin layer of thallous tellurate and heating said base and tellurate layer to a temperature of about 800° C. to convert said tellurate into a firmly adherent, vitreous layer of thallous tellurite.

7. A method of making a target for production of radioiodine by bombardment with high-velocity sub-atomic particles comprising the steps of coating the ridged surface of a copper plate with a relatively thin layer of thallous tellurate and heating said base and tellurate layer to form a firmly adherent, vitreous layer of thallous tellurite, the quantity of said tellurate applied being such as to give a tellurite layer of such a thickness as to reduce the energy of said particles to a value just below the threshold energy for production of radioiodine.

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REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name	Date
1,948,384	Lawrence	Feb. 20, 1934
2,009,457	Sloan	July 30, 1935
2,161,985	Szilard	June 13, 1939
2,206,634	Fermi	July 2, 1940
2,261,569	Schutze	Nov. 4, 1941

OTHER REFERENCES

Physical Review, vol. 53, page 1015 (1938); ibid., vol. 56, pp. 965-71 (1939); ibid., vol. 58, page 177 (1940).