PROCESS OF PRODUCING RADIO-ACTIVE ELEMENTS

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Fig. 1.

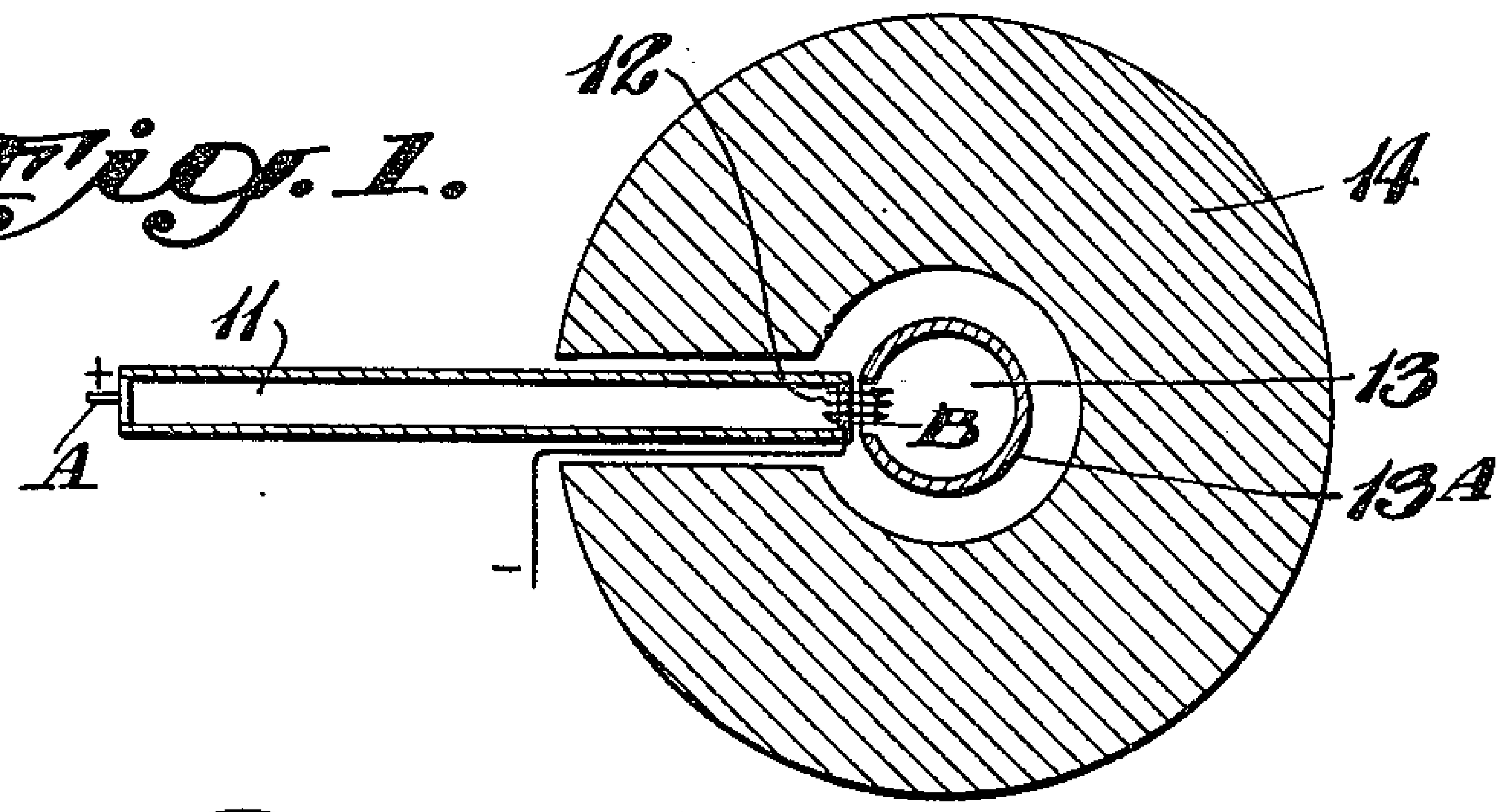

Fig. 3.

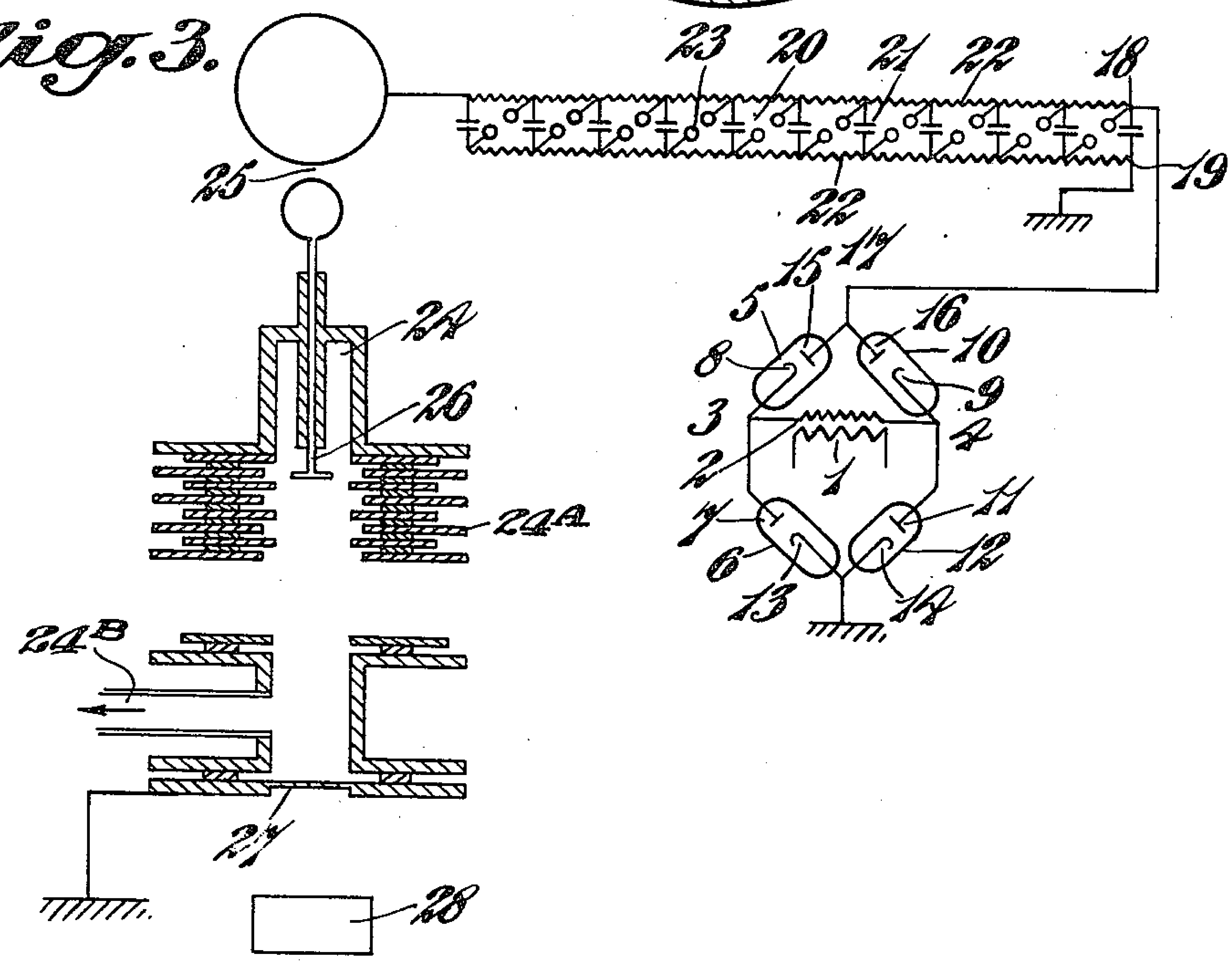

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Fig. 2.

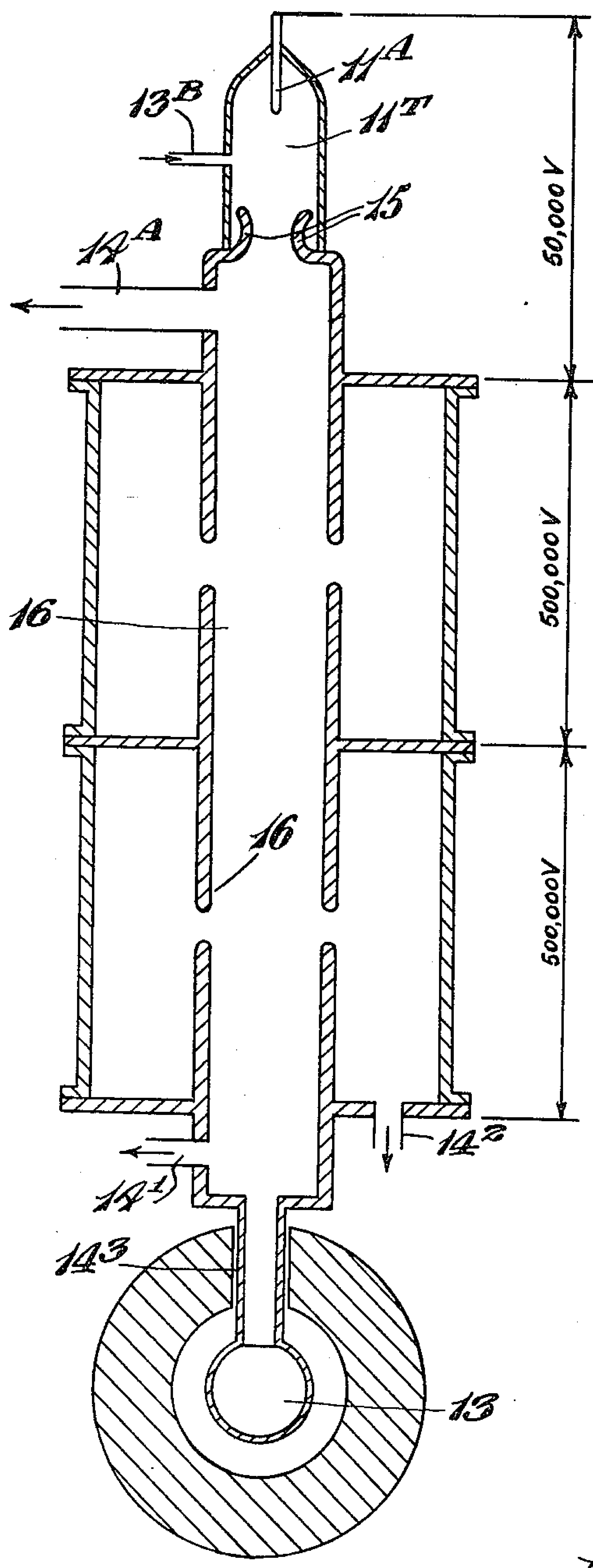

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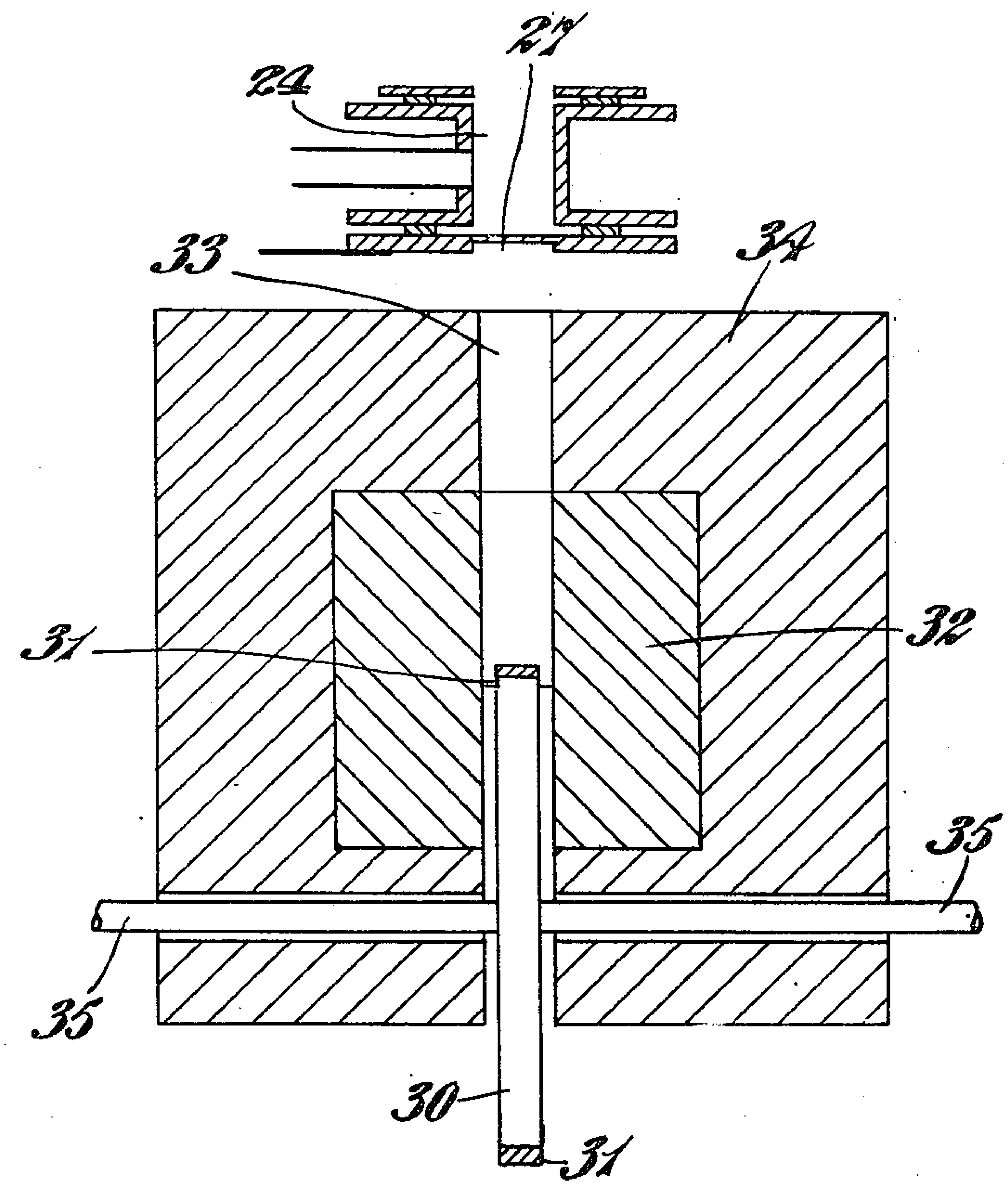
Fig. 4.



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UNITED STATES PATENT OFFICE

2,161,985

PROCESS OF PRODUCING RADIO-ACTIVE ELEMENTS

Leo Szilard, New York, N. Y.

Application March 11, 1935, Serial No. 10,500
In Great Britain March 12, 1934

9 Claims. (Cl. 204—31)

This invention concerns methods and apparatus for the generation of radio-active bodies.

According to one feature of my invention, radio-active elements may be produced from natural elements by bombarding a natural element or compounds of natural elements with neutrons produced in various ways, more particularly, by subjecting the natural elements to neutrons emanating from a target containing lithium, which target is subjected to a bombardment with fast deuterons. Another feature of the invention is directed to the production of radio-active elements from natural elements by exposing the natural elements to an irradiation with neutrons which are liberated from certain elements under the action of X-rays. Another feature of the invention is directed to chemically concentrating radio-active elements produced from natural elements if the radio-active element is isotopic with the natural element from which it is produced.

Other features of the invention will appear in the following detailed description referring to the drawings, and will be more particularly pointed out in the claims.

In the drawings,

Figure 1 represents a sectional elevation of an apparatus for carrying out the invention,

Figure 2 shows a more constructional lay-out of the apparatus of Figure 1,

Figure 3 shows the circuit arrangements for further modified apparatus and,

Figure 4 is a sectional view of apparatus intended to co-operate with that shown in Figure 3.

Referring first to Figure 1 of the drawings, 11 is an electrical discharge tube adapted to project a beam 12 of fast deuterons. The tube 11 is filled with deuterium and an anode A and cathode B are provided for connection to a source of high voltage. The deuterons are thus projected at high speed and pass through the cathode B. The deuterons fall on a substance 13 in a sealed container 13A. The substance 13 consists, for instance, of lithium. The collision of the fast diplogen ions with the substance 13 causes transmutation, i. e. a nuclear reaction of the deuteron with an atom of the target. The substance 13 is surrounded by a thick layer 14 containing the element which it is desired to transmute into a radio-active element. In order to have a high efficiency, the thickness of the layer 14 has to be sufficiently great, compared with the mean free path of the neutron, to prevent escape of any of the neutrons.

Figure 2 shows in more detail the electrical discharge tube 11 referred to in Figure 1. The tube essentially consists of a main portion 16 serving to accelerate the deuterons and an auxiliary tube 11T for initiating the flow. 11A is the anode and 15 the cathode of the auxiliary tube, deuterium being admitted thereto through the inlet 13B and being pumped away through the outlet 14A. The flow initiated by the auxiliary tube is accelerated by passage through the main tube 16 which is maintained exhausted by suction outlets 14^1 and 14^2, and which has a high potential gradient, there being a million volt potential difference between the ends of the tube. The accelerated deuterons emerge through the neck 14^3 of the tube 16 and collide with the substance 13 as described with reference to Figure 1 of the drawings.

If the substance 13 is a light element for instance lithium, then the bombardment by the accelerated deuterons results in emission of uncharged particles of mass of the order of magnitude of the mass of a proton. Such uncharged nuclei i. e. neutrons, penetrate even substances containing the heavier elements without ionisation losses, and will cause the formation of radio-active substances in the layer 14 exposed to them. It is to be noted that by the method so far described, the ionisation losses suffered by the deuterium nuclei are comparatively small in light elements and also that the substance to be made radio-active is irradiated with neutrons i. e. uncharged nuclei, which pass through even heavy elements without ionising them. The substance 14 exposed for treatment by the neutron radiation may be in the form of an organic compound for the purpose of carrying out separation of the generated radio-active element, as described more fully hereinafter.

Neutron radiation may also be produced by the action of X-rays upon an element having a dissociable neutron at the prevailing voltage, and apparatus for carrying out this process will now be described with reference to Figure 3 of the drawings.

In Figure 3, 1 is the primary of a transformer, the secondary 2 of which is connected to the junctions 3 and 4. The junction 3 is connected to the cathode 8 of the rectifier tube 5 and to the anode 7 of the rectifier tube 6. The junction 4 is connected to the cathode 9 of the rectifier tube 10 and to the anode 11 of the rectifier tube 12. The cathodes 13 and 14 are connected to each other and to earth. The anodes 15 and 16 are connected at 17, and fom this point are connected to the pole 18 of the impulse generator 20, the pole 19 of which is connected to earth. The impulse generator 20 is built of condensers 21, resistances 22 and spark-gap devices 23.

The impulse generator and rectifying unit shortly described above, are known components adapted to give an extremely high voltage for a fraction of a second. With such a system voltages up to 3 million volts have been obtained. The negative side of the impulse generator is connected to a spark gap device 25, which in turn is connected with the cathode 26 of the discharge tube 24. The latter is built up from rings 24A of which only a few are shown in the drawings. It will, however, be understood that the rings are continuous to enclose a space which is exhausted through the outlet 24B. The anode 27 of the tube is connected to earth and is formed by a metallic window. A body of material 28 is arranged at the external side of the window 27.

When the impulse generator operates to produce discharge between the cathode 26 and anode 27 of the tube 24, fast electrons penetrate the anode 27 and impinge upon the body 28. The latter when formed of Bi or Pb or some other heavy element, efficiently acts as an anti-cathode and hard X-rays are produced.

In Figure 4 of the drawings there is shown the lower portion of the discharge tube 24 with a device therebeneath for utilising the hard X-rays capable of being produced with the aid of the fast electrons emerging through the anode 27 of the tube 24. The device consists of a block 34 of the element which is to be made radio-active, a block 32 of an element with a dissociable neutron, being located therein. An aperture is formed in both the blocks 32 and 34 to allow entry of the cathode rays from the tube 24 above. The blocks 32 and 34 are also arranged to accommodate a wheel 30 and axle 35. The wheel 30 at its periphery carries a covering of tungsten or lead 31. The covering 31 acts as an anti-cathode and is cooled with water introduced along the bearing for the axle 35. The block 34 may be in the form of a cube having a length of side of 50 cm., whilst the block 32 can also be of cube form with a side of 25 cm. For the sake of example the block 34 may be formed of iodine or arsenic or other material which lends itself to being made radio-active. The block 32 may be of metallic beryllium. In order that an isotopic separation as described hereinafter may be performed after irradiation the material of the block 34 may be in the form of an organic compound. A voltage of 3 million volts may be used for the discharge tube and in operation the wheel 30 is rotated so that electrons passing through the anode 27 of the tube 24 hit the rotating anti-cathode covering 31. When the fast electrons strike the anti-cathode, hard X-rays are produced which penetrate the beryllium block 32 and cause neutrons to be released therefrom, which neutrons then act upon the block 34.

It may be that fast electrons and hard X-rays have a similar effect upon beryllium and one may therefore contemplate the making of the covering 31 of the wheel 30 from beryllium, the beryllium block 32 then being dispensed with, so that the neutrons released directly from the beryllium anti-cathode may enter and act upon the block 34.

It is found that when various elements are irradiated with neutrons by the process described above, practically all elements which become radio-active transmute into their own radio-active isotopes, and it becomes difficult to separate these radio-active isotopes from the remaining portion of the element unaffected. In order to achieve separation of the radio-active element from the non-radio-active part thereof the following process may be adopted. This process is based on the fact that if a compound of an element is irradiated by neutrons, and if an atom of the element transmutes into the radio-active isotope, then this atom is freed from the compound. In accordance with the process, a compound of the element it is desired to make radio-active is chosen such that the freed radio-active isotope of the element will not interchange with the combined atoms of the element within the compound, whereby the freed isotope may be chemically separated from the irradiated compound. Very often the element whose radio-active isotope is to be isolated, can be conveniently irradiated in the form of a compound in which it is bound to carbon. Thus in the case of iodine compounds such as iodoform or ethyl iodide, the radio-active iodine isotope may be chemically separated from the original iodine compound in the form of free iodine. In order to protect the radio-active iodine isotope a small amount of normal iodine may be dissolved in the organic iodine compound before irradiation or after irradiation but before separation.

What I claim and desire to secure by Letters Patent of the United States is:

1. The method of producing a radio-active element from a natural element by causing fast deuterons to impinge on a target containing lithium, and exposing a layer of the natural element to be transformed into a radio-active element to the neutron radiation emitted by the said target.

2. The method of producing from a natural element a concentrate of a radio-active element which is isotopic with the said natural element, which comprises subjecting a compound of said natural element to an irradiation which will transform some of said natural element into a radio-active isotope of said natural element, said compound of said natural element being one which in the environment in which the irradiation is being carried out does not interchange atoms of said natural element bound in the compound with atoms of said natural element or its isotopes outside the compound, and separating, after irradiation, from the compound said natural element and its isotopes which are outside the compound.

3. The method of producing from a natural element a concentrate of a radio-active element which is isotopic with said natural element, which comprises subjecting a compound of said natural element to irradiation with neutrons which will transform some of said natural element into a radio-active isotope of said natural element, said compound of said natural element being one which does not interchange in the environment in which the irradiation is carried out, atoms of said natural element bound in the compound with atoms of said natural element or its isotopes outside the compound, and separating, after irradiation, from the compound said natural element and its isotopes which are outside the compound.

4. The method of producing from a natural element a concentrate of a radio-active element which is isotopic with said natural element, which comprises irradiating with neutrons an organic compound of said natural element which will not interchange atoms of said natural ele-

ment bound in the compound with atoms of said natural element or its isotopes outside the compound, and separating, after irradiation, from the compound said natural element and its isotopes outside the compound.

5. The method of producing from a natural element a concentrate of a radio-active element which is isotopic with said natural element, which comprises irradiating with neutrons a compound which contains carbon, in which said natural element is bound to carbon and which compound will not interchange atoms of said natural element bound in the compound with atoms of said natural element or its isotopes outside the compound, and separating, after irradiation, from the compound said natural element and its isotopes outside the compound.

6. The method of producing from a natural element a radio-active element which is isotopic with the natural element comprising the steps of producing fast electrons, directing them toward a target adapted to produce X-rays under the impact of said electrons, exposing to the action of said X-rays an element of the class consisting of beryllium and heavy hydrogen which produce neutron radiation under the action of said X-rays, and producing a radio-active element from a natural element by exposing the natural element to said neutron radiation.

7. The method of producing from a natural element a radio-active element which is isotopic with the natural element comprising the steps of producing fast electrons having an energy of at least 3,000,000 volts, directing them toward a target adapted to produce X-rays under the impact of said electrons, exposing to the action of said X-rays an element of the class consisting of beryllium and heavy hydrogen from which neutrons are liberated by X-rays of 3,000,000 volts energy, and producing a radio-active element from a natural element by exposing the natural element to said neutron radiation.

8. The method of producing from a natural element a radio-active element which is isotopic with the natural element comprising the steps of producing fast electrons, directing them toward a target adapted to produce X-rays under the impact of said electrons, exposing beryllium to the action of said X-rays to produce neutron radiation, and producing a radio-active element from a natural element by exposing the natural element to said neutron radiation.

9. The method of producing from a natural element a radio-active element which is isotopic with said natural element comprising the steps of producing fast electrons, directing them toward a target adapted to produce X-rays under the impact of said electrons, exposing to the action of said X-rays an element of the class consisting of beryllium and heavy hydrogen which produce neutron radiation under the action of said X-rays, and irradiating by said neutron radiation a compound of said natural element which in the environment in which said irradiation is carried out will not interchange atoms of said natural element bound in the compound with atoms of said natural element or its isotopes outside the compound, and separating, after irradiation from the compound said natural element and its isotopes outside the compound.

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