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(54) **Method for Recycling Thallium-203 Isotope in Remnant Solution of Thallium-201 Radioisotope**

Verfahren zur Wiederverwertung eines Thallium-203-Isotops in einer Restlösung aus Thallium-201-Radioisotop

Procédé pour recycler un isotope de thallium 203 dans une solution restante d'un isotope de thallium 201

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Description**FIELD OF THE INVENTION**

[0001] The present invention relates to a method for recycling; more particularly, relates to recycling Thallium (TI)-203 isotope from a remnant electroplating solution of TI-203 target or a remnant chemical TI-201 solution with a recycling rate over 98% to be made into an electroplating solution or a solid thalious oxide used in nuclear medicine.

DESCRIPTION OF THE RELATED ART

[0002] A prior art, "Tumor Imaging Agent of Gallium Dimercaptosuccinate", is proclaimed in Taiwan, where a gallium(Ga)-67 dimercaptosuccinate compound having a dimercaptosuccinic acid labeled with Ga-67 radioisotope is obtained by a reaction of a radioactive ⁶⁷GaCl and a dimercaptosuccinic acid to be a tumor imaging agent. Nevertheless, a radioisotope is hard to obtain so that the price is high. And, the recycling of the radioisotope with the purification is done with high cost. Hence, the prior art does not fulfill users' requests on actual use.

SUMMARY OF THE INVENTION

[0003] The main purpose of the present invention is to provide a method for recycling TI-203 isotope with high purity and high recycling rate from a remnant solution of TI-201 radioisotope.

[0004] To achieve the above purpose, the present invention provides a method according to claim 1. Advantageous embodiments are laid down in the dependent claims.

[0005] More specifically, the invention provides a method for recycling TI-203 isotope in a remnant solution of TI-201 radioisotope, where, through a chemical precipitation, an amount of TI-203 precipitates is obtained in a remnant electroplating solution of TI-203 target or a remnant chemical TI-201 solution; the precipitates having TI-203 are collected and rinsed to obtain TI-203 isotopes; and, the TI-203 isotopes are dissolved in a sulphuric acid to obtain a target electroplating solution or are heated to 900°C to obtain a solid TI-203 oxide for easy storage. The present invention achieves a recycling rate over 98% and the chemical process flow is simple and convenient with high purity and high recycling rate through chemical precipitation and ion exchange; so, the present invention is used in an automatic or semi-automatic process to improve the convenience and the repetition of the recycling to save time and human resources. Accordingly, a novel method for recycling TI-203 isotope in a remnant solution of TI-201 radioisotope is obtained.

BRIEF DESCRIPTIONS OF THE DRAWINGS

[0006] The present invention will be better understood

from the following detailed descriptions of the preferred embodiments according to the present invention, taken in conjunction with the accompanying drawings, in which

- 5 FIG. 1 is a view showing a producing flow according to a first preferred embodiment of the present invention;
- FIG.2 is a view showing a producing flow according to a second preferred embodiment of the present invention;
- 10 FIG.3 is a view showing results of recycling TI-203 isotopes from remnant electroplating solutions according to the first preferred embodiment of the present invention;
- 15 FIG.4 is a view showing results of recycling TI-203 isotopes from remnant chemical solutions according to the second preferred embodiment of the present invention;
- FIG.5 is a view showing examination results of raw materials made of TI-203 isotopes recycled from remnant electroplating solutions according to the first preferred embodiment of the present invention;
- 20 FIG.6 is a view showing examination results of injections made of TI-203 isotopes recycled from remnant electroplating solutions according to the first preferred embodiment of the present invention;
- 25 FIG.7 is a view showing examination results of raw materials made of TI-203 isotopes recycled from remnant chemical solutions according to the second preferred embodiment of the present invention; and
- 30 FIG.8 is a view showing examination results of injections made of TI-203 isotopes recycled from remnant chemical solutions according to the second preferred embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0007] The following descriptions of the preferred embodiments are provided to understand the features and the structures of the present invention.

- 35 **[0008]** Please refer to FIG.1, which is a view showing a producing flow according to a first preferred embodiment of the present invention. As shown in the figure, the present invention is a method for recycling TL-203 isotope in a remnant solution of TL-201 radioisotope, where
- 40 a remnant electroplating solution of TL-203 target [11] is processed with an ion exchange [12] to remove an organic solvent; after processing the ion exchange [12], the remnant electroplating solution of TL-203 target [11] is washed [13] by using a sulphuric acid to obtain a TI-203 solution; a pH (Potential of Hydrogen) value of the
- 45 TI-203 solution is adjusted [14] by using a NaOH solution to obtain a TI-203 solution with a pH value of 12; the TI-203 solution with a pH value of 12 is precipitated [15] by

using a sulfide solution to obtain a solution having a black precipitate of thallous sulfide; the solution having a black precipitate of thallous sulfide is filtrated [16] by using a filtrating tank to separate the precipitate out of a recycled solution; and, the precipitate is rinsed [17] by using a NaOH solution to obtain a TI-203 isotope [18]. The TI-203 isotope [18] obtained is made into a solid thallous oxide by being heated to 900°C, or is made into a target electroplating solution with a dissolvent of sulphuric acid for recycling the TI-203 isotope with a recycling rate over 98%.

[0009] Please refer to FIG.2, which is a view showing a producing flow according to a second preferred embodiment of the present invention. As shown in the figure, the present invention is a method for recycling TL-203 isotope in a remnant solution of TL-201 radioisotope, where a pH value of a remnant chemical TI-201 solution [21] is adjusted [22] with a NaOH solution to obtain a TI-201 solution having a pH value of 12; the TI-201 solution having a pH value of 12 is precipitated [23] with a sulfide solution to obtain a solution having a precipitate of thallous sulfide; the solution having a precipitate of thallous sulfide is filtrated [24] by using a filtrating tank to separate the precipitate and a recycled solution; and, the precipitate is rinsed [25] with a NaOH solution to obtain a TI-203 isotope [26]. The TI-203 isotope [26] obtained can be heated to 900°C to obtain a solid thallous oxide, or be dissolved with a sulphuric acid to obtain a target electroplating solution. By doing so circularly, a recycling rate over 98% can be achieved.

[0010] Thus, a novel method for recycling TI-203 isotope in a remnant solution of TI-201 radioisotope is obtained. For further understanding the present invention, some preferred embodiments are described as follows:

[Example 1] Recycling TI-203 isotopes from remnant electroplating solutions of TI-203 targets

[0011] Please refer to FIG.3, which is a view showing results of recycling TI-203 isotopes from remnant electroplating solutions according to the first preferred embodiment of the present invention. As shown in the figure together with FIG.1 referred, an electroplating solution of TL-203 target comprises a thallium sulfide in an organic solvent. When the electroplating solution is processed through an electroplating until less than 1g (gram) of TI-203 is left, a remnant electroplating solution of TI-203 target [11] is obtained.

[0012] An ion exchange [12] is processed through the remnant electroplating solution of TI-203 target [11] by using a 1cm Φ x 10cm L ion-exchange tube for H₂SO₄-form cation exchange resin and a SJ-1211H rolling motor of ATTO Corp., Japan to remove the organic solvent and absorb the TI-203. After the ion exchange [12], TI-203 is washed down [13] by using a 4N sulphuric acid to obtain a TI-203 solution. A pH value of the TI-203 solution is then adjusted [14] by using a NaOH solution to obtain a TI-203 solution with a pH value of 12, where

the pH value after the adjusting [14] lies between 12 and 13.5. The TI-203 solution with a pH value of 12 is added with a saturated sulfide solution to be precipitated [15]. After being totally precipitated, the TI-203 solution is stayed steady for 1 hour to obtain a solution having black precipitate of thallous sulfide. The TI-203 solution is then moved into a semi-automatic vacuating filtration system, whose filtrating tank is of funnel-type made by KIMAX Corp. and whose filter plate is of elaborate-type with 4~5.5mm (millimeter) apertures, to be filtrated [16] to separate a precipitate out of a recycled solution. The recycled solution is poured into a wastes bucket, which can be circularly recycled for at least 20 times. The precipitate and the surfaces of the filtrating tank is rinsed [17] by using a NaOH solution and a distilled water to obtain a TI-203 isotopes [18]. The solution after the rinsing is collected to be recycled, whose recycling rate is at least 97% and whose actual recycling rate is over 98%. For easy storage, the TI-203 isotope [18] is heated to 900°C to obtain a solid thallous oxide, or is dissolved in a sulphuric acid to obtain a target electroplating solution through diluting and evaporating.

[Example 2] Recycling TI-203 isotopes from remnant chemical TI-201 solutions

[0013] Please refer to FIG.4, which is a view showing results of recycling TI-203 isotopes from remnant chemical solutions according to the second preferred embodiment of the present invention. As shown in the figure together with FIG.2 referred, a silver-plated target is electroplated with TI-203 isotope according to the irradiation requirement for producing a 201 thallous chloride (201TlCl). The target is irradiated by a cyclotron and is deposited to wait for a decay. Then the target is taken out to be dissolved by using a dense nitric acid. Through a coprecipitation and a separation with ferric nitrate and dense ammonium hydroxide, the junk solution separated is a remnant chemical TI-201 isolation solution [21], whose high-value condense TI-203 isotope is weighted like the isotope electroplated on the target. The remnant chemical TI-201 isolation solution [21] is deposited for 3~4 months for a decay and then is lifted for a recycling.

[0014] A pH value of the remnant chemical TI-201 isolation solution [21] is adjusted [22] with a NaOH solution to obtain a TI-201 solution having a pH value of 12, where the pH value after the adjusting [22] lies between 12 and 13.5. The TI-203 solution is then added with a saturated sulfide solution to be precipitated [23]. After being totally precipitated, the TI-203 solution is stayed steady for 1 hour to obtain a solution having a black precipitate of thallous sulfide. The TI-203 solution is then moved into a semi-automatic vacuating filtration system, whose filtrating tank is of funnel-type made by KIMAX Corp. and whose filter plate is of elaborate-type with 4~5.5mm (millimeter) apertures, to be filtrated [24] to separate a precipitate out of a recycled solution. The recycled solution is poured into a wastes bucket, which can be circularly

recycled for at least 20 times. The precipitate and the surfaces of the filtrating tank is rinsed [25] by using a NaOH solution and a distilled water to obtain TI-203 isotopes [26]. The solution after the rinsing is collected to be recycled, whose recycling rate is at least 97% and whose actual recycling rate is over 98%. For easy storage, the TI-203 isotope [26] is heated to 900°C to obtain a solid thallos oxide, or is dissolved in a sulphuric acid to obtain a target electroplating solution through diluting and evaporating.

[Example 3] An application of electroplating solutions of TL-203 target recycled from Example 1 and Example 2

[0015] Electroplating solutions of TL-203 target recycled from Example 1 and Example 2 are loaded in an electroplating tank. The electroplating solution of TL-203 target is processed through an electroplating on an irradiation target of a cyclotron having a copper bottom and a silver surface. The irradiation target of the cyclotron is transported to an irradiation station of the cyclotron to be irradiated with protons of 29MeV and 200μA. After an accumulation of 1500μAh through the irradiation, the irradiation target of the cyclotron is transported to a lead chamber for a chemical separation and purification. The Pb-201 isotope obtained after the nuclear reaction is deposited and is stayed steady for 32 hours to obtain TI-201 with high-purity and high-quality from the Pb-201 solution through the separation and purification. With a quality control to conform to nuclear-medicine quality, the TI-201 is made into an injection of 201TlCl to be used in a single photon emission computed tomography (SPECT) or a myocardium diagnosis.

[Example 4] An application of solid 203 thallos oxide recycled from Example 1 and Example 2.

[0016] The solid thallos-203 oxide recycled from Example 1 and Example 2 is dissolved in a sulphuric acid to obtain a TI-203 electroplating solution and is loaded in an electroplating tank. The TL-203 electroplating solution is processed through an electroplating on an irradiation target of a cyclotron having a copper bottom and a silver surface. The irradiation target of the cyclotron is transported to an irradiation station of the cyclotron to be irradiated with protons of 29MeV and 200μA. After an accumulation of 1500μAh through the irradiation, the irradiation target of the cyclotron is transported to a lead chamber for chemical separation and purification. The Pb-201 isotope obtained after the nuclear reaction is deposited and is stayed steady for 32 hours to obtain TI-201 with high-purity and high-quality from the Pb-201 solution through the separation and purification. With a quality control to conform to nuclear-medicine quality, the TI-201 is made into an injection of 201TlCl to be used in a SPECT or a myocardium diagnosis.

[0017] The raw materials recycled from the remnant of target electroplating solution or chemical solution and

the injections made with the raw materials are examined and are all passed as shown in FIG.5 to FIG.8. To sum up, the present invention is a method for recycling TL-203 isotope in a remnant solution of TL-201 radioisotope, where a recycling rate over 98% is achieved and the chemical process flow is simple and convenient with high purity and high recycling rate through chemical precipitation and ion exchange. The present invention is used in an automatic or semi-automatic process, which improves the convenience and the repetition of the recycling and saves time and human resources.

[0018] The preferred embodiments herein disclosed are not intended to unnecessarily limit the scope of the invention as set out in the claims.

Claims

1. A method for recycling T1-203 isotope in a remnant solution of TL-201 radioisotope, comprising steps of:

- adjusting pH value with a NaOH solution to obtain a second solution having a pH value of 12;
- settling or precipitating said second solution with a sulfide solution to obtain a solution having a precipitate of thallos sulfide;
- filtrating said solution having a precipitate of thallos sulfide with a filtrating tank to obtain said precipitate and a recycled solution; and
- rinsing said precipitate with a NaOH solution to obtain T1-203 isotopes.

2. The method according to claim 1, comprising steps of:

- adjusting a pH value of a remnant chemical TI-201 solution with a NaOH solution to obtain a T1-201 solution having a pH value of 12;
- precipitating said T1-201 solution having a pH value of 12 with a sulfide solution to obtain a second solution having a precipitate of thallos sulfide;
- filtrating said solution having a precipitate of thallos sulfide with a filtrating tank to obtain said precipitate and a recycled solution; and
- rinsing said precipitate with a NaOH solution to obtain T1-203 isotopes.

3. The method according to claim 1, comprising steps of:

- processing an ion exchange to a remnant electroplating solution of TL-203 target;
- washing said remnant electroplating solution with a sulphuric acid to obtain a first T1-203 solution;
- adjusting pH value of said first TI-203 solution with a NaOH solution to obtain a second T1-203

- solution having a pH value of 12;
 - settling said second TI-203 solution with a sulfide solution to obtain a solution having a precipitate of thallous sulfide;
 - filtrating said solution having a precipitate of thallous sulfide with a filtrating tank to obtain said precipitate and a recycled solution; and
 - rinsing said precipitate with a NaOH solution to obtain T1-203 isotopes.
4. The method according to one of claims 1 to 3, wherein said T1-203 isotope is made into a solid thallous oxide.
5. The method according to claim 4, wherein said solid thallous oxide is obtained by heating said T1-203 isotope to 900°C.
6. The method according to one of claims 1 to 3, wherein a target electroplating solution is obtained by adding said TI-203 isotope.
7. The method according to claim 6, wherein said target electroplating solution is obtained with a dissolvent of sulfuric acid.
8. The method according to claim 6, wherein a method for obtaining said target electroplating solution comprises diluting and evaporating.
9. The method according to one of claims 1 to 8, wherein a recycling rate of said T1-203 isotope is over 98%.
10. The method according to one of claims 1 to 9, wherein said TI-203 isotope is a raw material for a nucleomedical injection of 201 thallous chloride (201TlCl).
11. The method according to claim 10, wherein an irradiator to said injection is a cyclotron.
12. The method according to one of claims 1 to 11, wherein said pH value after said adjusting pH value is a value between 12 and 13.5; and wherein a recycling rate for said recycled solution is at least 97%.
13. The method according to one of claims 1 to 12, wherein said recycled solution is recycled more than 20 times.

Patentansprüche

1. Verfahren zur Wiederaufbereitung eines TI-203-Isotop, in einer Restlösung aus TI-201-Radioisotop, umfassend die Schritte:
- Einstellen des pH-Werts mit einer NaOH-Lösung, um eine zweite Lösung mit einem pH-Wert

von 12 zu erhalten;
 - Absetzen oder Ausfällen der zweiten Lösung mit einer Sulfidlösung, um eine Lösung mit einem Niederschlag aus Thalliumsulfid zu erhalten;
 - Filtrieren der Lösung, welche einen Niederschlag aus Thalliumsulfid aufweist, mit einem Filtrationstank, um den Niederschlag und eine wiederaufbereitete Lösung zu erhalten; und
 - Spülen des Niederschlags mit einer NaOH-Lösung, um T1-203-Isotope zu erhalten.

2. Verfahren nach Anspruch 1, umfassend die Schritte:

- Einstellen eines pH-Werts einer chemischen T1-201-Restlösung mit einer NaOH-Lösung, um eine T1-201-Lösung mit einem pH-Wert von 12 zu erhalten;
 - Ausfällen der T1-201-Lösung, die einen pH-Wert von 12 aufweist, mit einer Sulfidlösung, um eine zweite Lösung zu erhalten, die ein Niederschlag aus Thalliumsulfid enthält;
 - Filtrieren der Lösung, welche einen Niederschlag aus Thalliumsulfid aufweist, mit einem Filtrationstank, um den Niederschlag und eine wiederaufbereitete Lösung zu erhalten; und
 - Spülen des Niederschlags mit einer NaOH-Lösung, um T1-203-Isotope zu erhalten.

3. Verfahren nach Anspruch 1, umfassend die Schritte:

- Durchführen eines Ionenaustauschs an einer Rest-Elektroplattierlösung eines T1-203-Targets;
 - Waschen der Rest-Elektroplattierlösung mit einer Schwefelsäure, um eine erste T1-203-Lösung zu erhalten;
 - Einstellen des pH-Werts der ersten T1-203-Lösung mit einer NaOH-Lösung, um eine zweite T1-203-Lösung mit einem pH-Wert von 12 zu erhalten;
 - Ausfällen der zweiten TI-203-Lösung mit einer Sulfidlösung, um eine Lösung mit einem Niederschlag aus Thalliumsulfid zu erhalten;
 - Filtrieren der Lösung, welche einen Niederschlag aus Thalliumsulfid aufweist, mit einem Filtrationstank, um den Niederschlag und eine wiederaufbereitete Lösung zu erhalten; und
 - Spülen des Niederschlags mit einer NaOH-Lösung, um TI-203-Isotope zu erhalten.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei das TI-203-Isotop zu einem festen Thalliumoxid be- reitet wird.

5. Verfahren nach Anspruch 4, wobei das feste Thalliumoxid durch Erwärmen des TI-203-Isotops auf 900°C erhalten wird.

6. Verfahren nach einem der Ansprüche 1 bis 3, wobei eine Target-Elektroplattierlösung durch Hinzufügen des TI-203-Isotops erhalten wird.
7. Verfahren nach Anspruch 6, wobei die Target-Elektroplattierlösung mit einem Lösungsmittel aus Schwefelsäure erhalten wird. 5
8. Verfahren nach Anspruch 6, wobei ein Verfahren zum Erhalten der Target-Elektroplattierlösung Verdünnen und Evaporieren umfasst. 10
9. Verfahren nach einem der Ansprüche 1 bis 8, wobei eine Wiederaufbereitungsrate des TI-203-Isotops bei über 98% liegt. 15
10. Verfahren nach einem der Ansprüche 1 bis 9, wobei das TI-203-Isotop ein Rohmaterial für eine nuklearmedizinische Injektion von 201-Thalliumchlorid ($^{201}\text{TlCl}$) ist. 20
11. Verfahren nach Anspruch 10, wobei ein Strahler für diese Injektion ein Zyklotron ist.
12. Verfahren nach einem der Ansprüche 1 bis 11, wobei der pH-Wert nach dem Anpassen des pH-Werts ein Wert zwischen 12 und 13,5 ist, und wobei eine Wiederaufbereitungsrate für die wiederaufbereitete Lösung mindestens 97% beträgt. 25
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13. Verfahren nach einem der Ansprüche 1 bis 12, wobei die wiederaufbereitete Lösung mehr als 20-mal wiederaufbereitet ist. 35
- Revendications**
1. Procédé de recyclage d'isotope TI-203 dans une solution résiduelle de radioisotope TI-201 comprenant les étapes : 40
- d'ajustage du pH avec une solution de NaOH pour obtenir une seconde solution ayant un pH de 12;
 - de fixation ou de précipitation de la seconde solution avec une solution de sulfure pour obtenir une solution ayant un précipité de sulfure thalieux ;
 - de filtration de la solution ayant un précipité de sulfure thalieux avec un filtrateur pour obtenir le précipité et une solution recyclée et
 - de rinçage du précipité avec une solution de NaOH pour obtenir des isotopes TI-203. 45
2. Procédé selon la revendication 1 comprenant les étapes : 50
- d'ajustage du pH d'une solution résiduelle chimique de TI-201 avec une solution de NaOH pour obtenir une solution de TI-201 ayant un pH de 12 ;
 - de précipitation de la solution de TI-201 ayant un pH de 12 avec une solution de sulfure pour obtenir une seconde solution ayant un précipité de sulfure thalieux ;
 - de filtration de la solution ayant un précipité de sulfure thalieux avec un filtrateur pour obtenir le précipité et une solution recyclée et
 - de rinçage du précipité avec une solution de NaOH pour obtenir des isotopes TI-203, 55
3. Procédé selon la revendication 1 comprenant les étapes :
- de traitement d'un échange d'ions sur une solution résiduelle d'électrodéposition cible de TI-203 ;
 - de lavage de la solution résiduelle d'électrodéposition avec un acide sulfurique pour obtenir une première solution de TI-203 ;
 - d'ajustage du pH de la première solution de TI-203 avec une solution de NaOH pour obtenir une seconde solution de TI-203 ayant une valeur de pH de 12 ;
 - de fixation de la seconde solution de TI-203 avec une solution de sulfure pour obtenir une solution ayant un précipité de sulfure thalieux ;
 - de filtration de la solution ayant un précipité de sulfure thalieux avec un filtrateur pour obtenir le précipité et une solution recyclée et
 - de rinçage du précipité avec une solution de NaOH pour obtenir des isotopes TI-203.
4. Procédé selon l'une des revendications 1 à 3 dans lequel l'isotope TI-203 est transformé en oxyde thalieux.
5. Procédé selon la revendication 4 dans lequel l'oxyde thalieux solide est obtenu en chauffant l'isotope TI-203 à 900 °C.
6. Procédé selon l'une des revendications 1 à 3 dans lequel une solution d'électrodéposition cible est obtenue en ajoutant l'isotope TI-203.
7. Procédé selon la revendication 6 dans lequel la solution d'électrodéposition cible est obtenue avec un solvant d'acide sulfurique.
8. Procédé selon la revendication 6 dans lequel un procédé pour obtenir la solution d'électrodéposition cible comprend la dilution et l'évaporation.
9. Procédé selon l'une des revendications 1 à 8 dans lequel un taux de recyclage de l'isotope TI-203 est supérieur à 98%.

- 10.** Procédé selon l'une des revendications 1 à 9 dans lequel l'isotope TI-203 est un matériau brut pour une injection de médecine nucléaire de chlorure thalleux 201 (TICI201). 5
- 11.** Procédé selon la revendication 10 dans lequel un irradiateur pour l'injection est un cyclotron.
- 12.** Procédé selon l'une des revendications 1 à 11 dans lequel le pH après ajustage du pH est une valeur entre 12 et 13,5 et dans lequel un taux de recyclage de la solution recyclée est d'au moins 97%. 10
- 13.** Procédé selon l'une des revendications 1 à 12 dans lequel la solution recyclée est recyclée plus de 20 fois. 15

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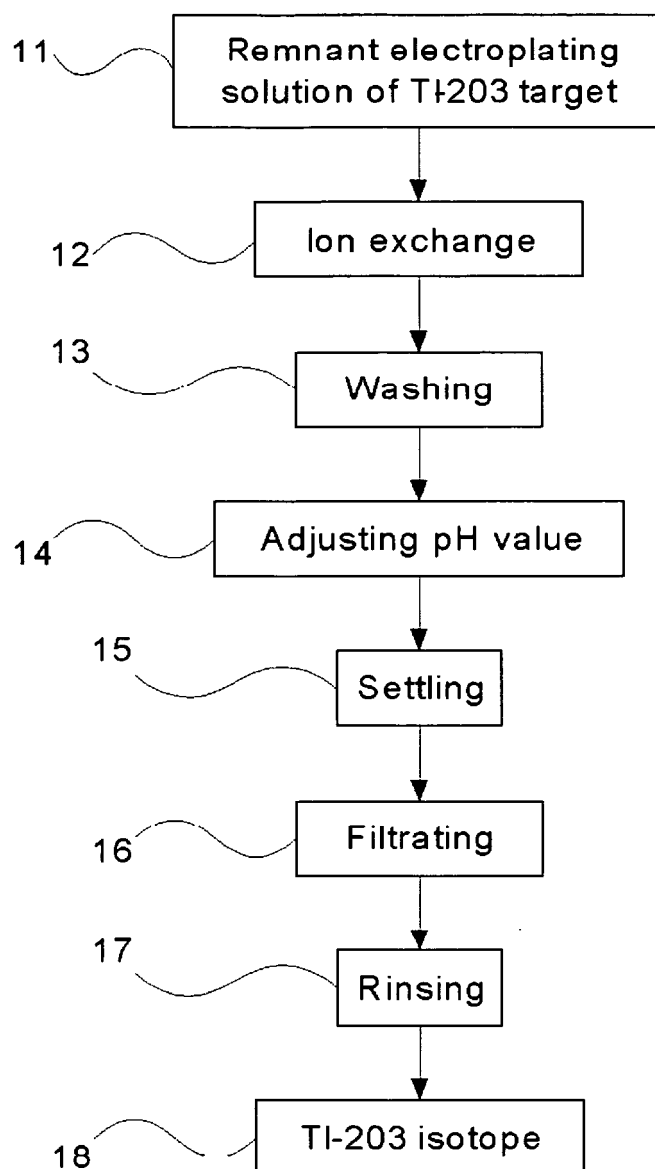
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**FIG.1**

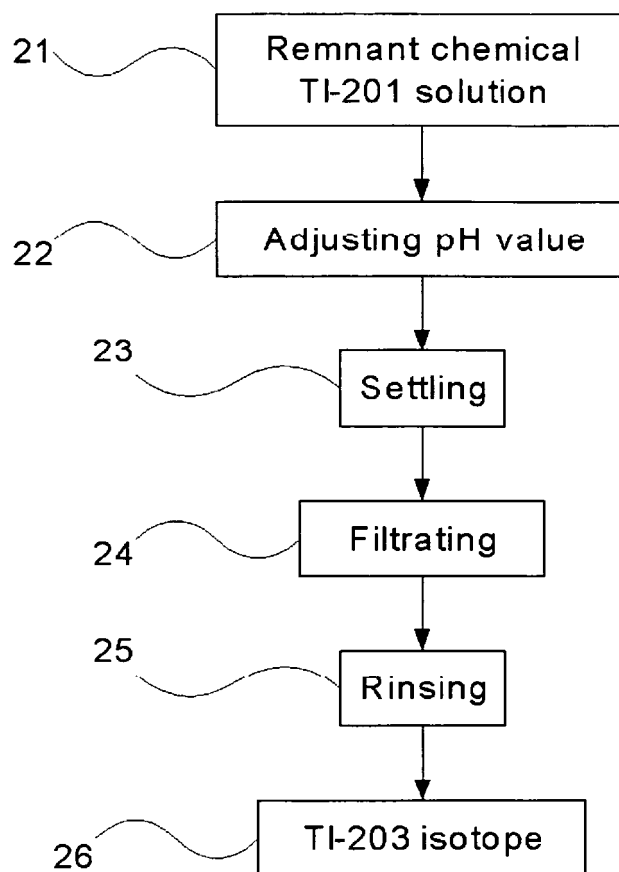


FIG.2

Samples	TI-203 added (g)	S a m p l e s o l u t i o n v o l u m e (mL)	TI - 2 0 3 c o n t e n t (mg/mL)	Recycled TI-203 (g)	Recycling rate (%)	A v e r a g e R e c y c l i n g r a t e (%)
I-3A-5A	0.426	204	2.090	0.416	97.57	98.75
I-3B-5B	0.427	205	2.090	0.426	99.52	
I-7A-9A	0.429	204	2.105	0.427	99.45	
I-7A-7A	0.427	203	2.105	0.421	98.59	
I-15A-17A	0.433	201	2.155	0.427	98.61	
I-15B-17B	0.433	201	2.155	0.424	97.92	
I-23A-23A	0.421	206	2.045	0.415	98.57	
2 C-1 ~ 10	0.785	150	5.230	0.772	98.34	
4 C-1 ~ 17	0.525	134	3.920	0.521	99.24	
1B-1 ~ 30	0.305	238	1.280	0.304	99.67	

FIG. 3

Samples	TI-203 (g)	S a m p l e s o l u t i o n v o l u m e (mL)	TI - 203 c o n t e n t (mg/mL)	Recycled TI-203 (g)	Recycling rate (%)	A v e r a g e R e c y c l i n g r a t e (%)
99002	0.626	187	3.350	0.620	98.97	98.61
99006	0.625	192	3.257	0.619	99.04	
99025	0.622	205	3.030	0.609	97.91	
99036	0.599	189	3.170	0.593	98.98	
99053	0.610	196	3.110	0.603	98.92	
99054	1.526	243	6.279	1.511	99.02	
99058	1.500	248	6.040	1.462	97.47	
99059	0.610	202	3.020	0.592	97.05	
0302004	2.115	155	13.500	2.093	98.96	
0302010	1.961	163.4	12.000	1.956	99.75	

FIG.4

Prod. S / N	MT03004008	MT03004009	MT03004010	MT03004011	MT03004012	MT03004013	MT03004014	MT03004015	MT03004016	MT03004017
Manufact. Day	93.2.25	93.3.3	93.3.10	93.3.17	93.3.24	93.3.31	93.4.7	93.4.14	93.4.21	93.4.28
Reciev. Day	93.2.26	93.3.4	93.3.11	93.3.18	93.3.25	93.4.1	93.4.8	93.4.15	93.4.22	93.4.29
Correct. Time	93.3.4	93.3.11	93.3.18	93.3.25	93.4.1	93.4.8	93.4.15	93.4.22	93.4.29	93.5.6
	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00
Exam results of raw materials										
Quality (colorless clear solution)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Tl-201 nuclear source exam (gamma-ray spectroscopy with main crest at 167keV and sub-crest at 135keV)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Acidity (3~7)	5.0	5.5	5.3	5.3	5.5	5.5	5.3	5.5	5.3	5.3
Radioactivity on Reciev. Day (not lower than 15mCi/mL)	188.5 mCi/mL	171.0 mCi/mL	212.3 mCi/mL	176.0 mCi/mL	176.0 mCi/mL	190.0 mCi/mL	216.0 mCi/mL	215.0 mCi/mL	177.0 mCi/mL	187.0 mCi/mL
Tl-201 (not lower than 95.0%)	99.03%	99.11%	99.22%	98.84%	98.76%	98.80%	99.41%	98.75%	98.97%	98.99%
Nuclear source purity more than 2.0%	0.02%	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%	0.02%	0.01%	0.02%
Tl-202 (not more than 2.7%)	0.95%	0.87%	0.76%	1.14%	1.23%	1.19%	0.57%	1.23%	1.02%	0.99%
Pb-203 (not more than 0.3%)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Tl metal ion smaller than 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi
Cu metal ion smaller than 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi
Fe metal ion smaller than 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi
Result	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

FIG.5

Exam results of raw materials										
Pr o d . S / N	T04008A	T04009A	T04010A	T04011A	T04012A	T04013A	T04014A	T04015A	T04016A	T04017A
Manufact. Day	93.2.26.	93.3.4.	93.3.11.	93.3.18.	93.3.25.	93.4.1.	93.4.8.	93.4.15.	93.4.22.	93.4.29.
Reciev. Day	93.3.12.	93.3.19.	93.3.26.	93.4.2.	93.4.9.	93.4.16.	93.4.23.	93.4.30.	93.5.7.	93.5.14.
Correct. Time	93.3.49	93.3.11	93.3.18	93.3.25	93.4.1	93.4.8	93.4.15	93.4.22	93.4.29	93.5.6
	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00
Exam results of raw materials										
Quality (colorless clear solution)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Acidity(4.5~7.0)	5.5	5.5	5.3	5.5	5.5	5.5	5.5	5.5	5.5	5.3
Radio-chemical purity	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Nuclear source purity at Correct. Time	TI-201 (not lower than 95.0%)	99.12%	99.11%	99.21%	98.96%	98.77%	98.65%	99.41%	98.80%	99.00%
	TI-200 (not more than 2.0%)	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%
	TI-202 (not more than 2.7%)	0.86%	0.87%	0.78%	1.02%	1.21%	1.33%	0.57%	1.18%	0.98%
	Pb-203 (not more than 0.3%)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Radioactivity* (8.5 ~ 10.6 mCi)	10.49 mCi	10.06 mCi	10.10 mCi	10.26 mCi	10.23 mCi	10.41 mCi	9.90 mCi	9.99 mCi	9.95 mCi	10.16 mCi
Chemical purity	Ti metal ion smaller than 2 µg / mL	< 2µg/mL	< 2µg/mL	< 2µg/mL	< 2µg/mL	< 2µg/mL	< 2µg/mL	< 2µg/mL	< 2µg/mL	< 2µg/mL
	Cu metal ion smaller than 5 µg / mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL
	Fe metal ion smaller than 5 µg / mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL	< 5µg/mL
	Toxin test in germ(not more than 25 EU / mL)	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL
Germless test	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Result	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

FIG. 6

P r o d .	S / N	MT03004018	MT03004019	MT03004020	MT03004021	MT03004022	MT03004023	MT03004024	MT03004025	MT03004026	MT03004027
Manufact. Day	93.5.5	93.5.12	93.5.19	93.5.26	93.6.2	93.6.9	93.6.16	93.6.23	93.6.30	93.7.7	93.7.14
Reciev. Day	93.5.6	93.5.13	93.5.20	93.5.27	93.6.3	93.6.10	93.6.17	93.6.24	93.7.1	93.7.8	93.7.15
Correct. Time	93.5.13	93.5.20	93.5.27	93.6.3	93.6.10	93.6.17	93.6.24	93.7.1	93.7.8	93.7.15	93.7.22
	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00
Exam results of raw materials											
Quality (colorless clear solution)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Tl-201 nuclear source exam (gamma-ray spectroscopy with main crest at 167keV and sub-crest at 135keV)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Acidity (3~7)	5.3	5.0	5.3	5.3	5.3	5.5	4.4	4.7	4.7	4.0	4.0
Radioactivity on Reciev. Day (not lower than 15 mCi/mL)	163.0 mCi/mL	152.0 mCi/mL	170.0 mCi/mL	208.0 mCi/mL	149.0 mCi/mL	142.0 mCi/mL	177.8 mCi/mL	127.0 mCi/mL	161.0 mCi/mL	180.0 mCi/mL	180.0 mCi/mL
Tl-201 (not lower than 95.0%)	98.99%	99.16%	99.34%	99.05%	97.71%	99.26%	99.13%	98.83%	99.16%	99.27%	99.27%
Tl-200 (not more than 2.0%)	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%	0.02%	0.01%	0.01%	0.02%	0.02%
Tl-202 (not more than 2.7%)	0.99%	0.82%	0.64%	0.93%	2.28%	0.73%	0.85%	1.16%	0.83%	0.71%	0.71%
Pb-203 (not more than 0.3%)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Tl metal ion smaller than 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi	< 0.4µg/mCi
Cu metal ion smaller than 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi
Fe metal ion smaller than 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi	< 1µg/mCi
Result	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

FIG. 7

Prod. S / N	T04018A	T04019A	T04020A	T04021A	T04022A	T04023A	T04024A	T04025A	T04026A	T04027A
Manufact. Day	93.5.6.	93.5.13.	93.5.20.	93.5.27.	93.6.3.	93.6.10.	93.6.17.	93.6.24.	93.7.1.	93.7.8.
Reciev. Day	93.5.21.	93.5.28.	93.6.4.	93.6.11.	93.6.18.	93.6.25.	93.7.2.	93.7.9.	93.7.16.	93.7.23.
Correct. Time	93.5.13	93.5.20	93.5.27	93.6.3	93.6.10	93.6.17	93.6.24	93.7.1	93.7.8	93.7.15
	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00	17:00
Exam results of raw materials										
Quality (colorless clear solution)	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Acidity (4.5~7.0)	5.3	5.3	5.5	5.5	5.3	5.3	5.0	5.0	5.0	5.0
Radio-chemical purity	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
TI-201 (not lower than 95.0%)	99.03%	99.23%	99.38%	99.04%	97.65%	99.17%	99.05%	98.88%	99.09%	99.24%
TI-200 (not more than 2.0%)	0.02%	0.02%	0.02%	0.02%	0.01%	0.02%	0.02%	0.01%	0.01%	0.02%
TI-202 (not more than 2.7%)	0.95%	0.75%	0.60%	0.94%	2.34%	0.81%	0.93%	1.10%	0.90%	0.75%
Pb-203 (not more than 0.3%)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Radioactivity* (8.6 ~ 10.6 mCi)	10.10mCi	9.89mCi	9.79mC	10.21mCi	10.32mCi	10.09mCi	10.07mCi	10.04mCi	10.13mCi	10.15mCi
Chemical purity	TI metal ion smaller than 2 µg / mL Cu metal ion smaller than 5 µg / mL Fe metal ion smaller than 5 µg / mL	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/m- < 5µg/m- < 5µg/m-	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/mL < 5µg/mL < 5µg/mL	< 2µg/mL < 5µg/mL < 5µg/mL
Toxin test in germ(not more than 25 EU / mL)	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL	< 0.6EU/mL
Germless test	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
Result	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

FIG. 8