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English

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G21G 1/100 (2006.01)

(54) Title: ECONOMICAL PRODUCTION OF ISOTOPES USING QUANTIZED TARGET IRRADIATION

(57) Abstract: A process for producing isotopes by continuously flowing a liquid stream, carrying capsules of target nuclei (NP-237) in solution, through a nuclear reactor (a TRIGA style nuclear reactor). Upon removal from the core of the nuclear reactor and after allowing for the decay of Np-238 to Pu-238, the capsules are emptied and the mixture of elements and isotopes are chemically separated using solvent extraction or ion exchange. Isotopes that are capable of further processing into Pu-238 are recycled to the core for further processing.
INTERNATIONAL SEARCH REPORT

INTERNATIONAL SEARCH REPORT

International application No. PCT/US 12/52818

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G21 G 1/00 (2013.01)
USPC - 376/1 92

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8): G21G 1/00 (2013.01)
UCPC: 376/192

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

IPC(8): G21G 1/00 (2013.01)
UCPC: 376/192; 210/263; 376/194; 376/195

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase; Google Scholar; Google Patent

Search Terms Used: capsule encapsulate seed coat neutron isotope polymer polyester target fluid slurry suspension reactor core tube pipe pump coil recover separate isolate purify column

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US 2007/0297554 A1 (Lavie et al.) 27 December 2007 (27.12.2007), para. [0075], [0076], Fig. 8</td>
<td>6</td>
</tr>
<tr>
<td>A</td>
<td>WO 2011/093938 A2 (Tsang) 04 August 2011 (04.08.2011), para. [0001]-[0139], Fig. 1-10</td>
<td>1-14</td>
</tr>
</tbody>
</table>

Date of the actual completion of the international search
30 April 2013 (30.04.2013)

Date of mailing of the international search report
17 JUN 2013

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450
Facsimile No. 571-273-3201

Authorized officer: Lee W. Young
PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

Form PCT/ISA/2 10 (second sheet) (July 2009)
### INTERNATIONAL SEARCH REPORT

**International application No.**
PCT/US 12/52818

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. □ Claims Nos.:
   
   because they relate to subject matter not required to be searched by this Authority, namely:

2. □ Claims Nos.:
   
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. □ Claims Nos.:
   
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

See Extra Sheet (below).

1. □ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. □ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. □ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. □ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos. 1-14

**Remark on Protest**

□ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

□ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

□ No protest accompanied the payment of additional search fees.

Form PCT/ISA/2 10 (continuation of first sheet (2)) (July 2009)
This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I: Claims 1-14 drawn to a method and an apparatus for producing isotopes, comprising hollow tubing configured to be arranged around a nuclear reactor core and further configured to contain a circulating capsule-bearing fluid, said capsules containing a solution of a material to be irradiated; a pump configured to force said circulating capsule-bearing fluid through said hollow tubing; a capsule loading station configured to introduce a solution of starting material into capsules; a capsule introduction station configured to introduce the capsules into said capsule-bearing fluid; a capsule withdrawal station configured to withdraw irradiated capsules from said circulating fluid and remove irradiated sample from said capsules; a separation station configured to receive said irradiated sample and separate a desired isotope from incomplete products and undesired products.

Group II: Claims 15-19 drawn to a method for separating a desired isotope, resulting from the irradiation of a starting material in a nuclear reactor, from a starting material, comprising: providing irradiated solution containing the desired isotope and the starting material to an ion exchange resin conditioned to adsorb the desired isotope and starting material, separating them from a carrier solution; treating said ion exchange resin including adsorbed desired isotope and starting material with an eluting reagent selected to elute the desired isotope leaving the starting material adsorbed to said ion exchange resin; treating said ion exchange resin including adsorbed starting material with an eluting reagent selected to elute the adsorbed starting material.

The inventions listed as Groups I through II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

Group I includes the technical feature of hollow tubing configured to be arranged around a nuclear reactor core and further configured to contain a circulating capsule-bearing fluid, said capsules containing a solution of a material to be irradiated, not found in group II.

Group II includes the technical feature of an ion exchange resin conditioned to adsorb the desired isotope and starting material, not found in group I.

Further:
The only technical feature shared by Groups I and II that would otherwise unify the groups, is separating a desired isotope, resulting from the irradiation of a starting material in a nuclear reactor, from a starting material. However, this shared technical feature does not represent a contribution over prior art, because the shared technical feature is disclosed by US 4,487,738 A (O'Brien, Jr. et al.) 11 December 1984 (11.12.1984). O'Brien Jr. et al. discloses separating a desired isotope, resulting from the irradiation of a starting material in a nuclear reactor, from a starting material (col 2, in 40-45; col 2, in 3-4).

As the technical feature was known in the art at the time of the invention, this cannot be considered a special technical feature that would otherwise unify the groups.

Groups I and II, therefore, lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.

Note: Claim 7, as drafted, refers to "the method of claim 1." Claim 1 is, however, drawn to an apparatus. For purposes of this determination, claim 7 is presumed to refer to "the apparatus of claim 1."