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Simulated moving-bed type chromatographic separation method and simulated moving-bed type chromatographic separation system

Abstract

A simulated moving-bed type chromatographic separation method including separating a weakly adsorptive component, a strongly adsorptive component, and an intermediately adsorptive component that has adsorptive property intermediate between the two components, with respect to an adsorbent, with two or more kinds of eluents by using a circulation system in which a plurality of unit packed columns each packed with an adsorbent are connected in series and in an endless form via pipes, the weakly adsorptive component, the strongly adsorptive component, and the intermediately adsorptive component being contained in a feed solution, wherein a feed solution supply port, eluent supply ports and a plurality of extraction ports are provided on the pipes of the circulation system, and positions of the feed solution supply port and the plurality of extraction ports are set to have a specified relationship; and a chromatographic separation system suitable for implementing the chromatographic separation method.

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Background/Summary

FIELD OF THE INVENTION

(1) The present invention relates to a simulated moving-bed type chromatographic separation method and a simulated moving-bed type chromatographic separation system.

BACKGROUND OF THE INVENTION

(2) In chromatographic separation by a simulated moving-bed scheme, a circulation system is constructed in which a plurality of unit packed columns (hereinafter, also simply referred to as "packed columns", and may be called "columns") packed with an adsorbent having a selective adsorption ability with respect to a specific component of two or more components contained in a feed solution are connected in series via pipes and the packed column at the most downstream portion and the packed column at the most upstream portion are connected in an endless form. A feed solution and an eluent are supplied to this circulation system, a fraction with a fast moving velocity (weakly adsorptive fraction), a fraction with a slow moving velocity (strongly adsorptive fraction), and, if necessary, a fraction with an intermediate moving velocity (intermediately adsorptive fraction) in the circulation system are extracted from different positions, respectively, and then, the feed solution supply position, the eluent supply position, the extraction position of the weakly adsorptive fraction, the extraction position of the intermediately adsorptive fraction, and the extraction position of the strongly adsorptive fraction are shifted toward the fluid circulation

direction of the circulation system while maintaining a certain positional relationship. By repeating this operation, processing operations of the moving bed capable of continuously performing feed solution supply are artificially achieved.

(3) Patent Literature 1 discloses a method of continuously separating three or more fractions differing in affinity for an adsorbent by repeating, to a single improved simulated moving-bed apparatus, a step of extracting an intermediately adsorptive fraction while supplying an eluent and a feed solution and a step of extracting a weakly adsorptive fraction and a strongly adsorptive fraction while supplying an eluent.

(4) In conventionally general chromatographic separation by a simulated moving-bed scheme including the technique described in Patent Literature 1, basically, one kind of eluent is used. Therefore, in a case where a feed solution containing a component having strong adsorptive property with respect to an adsorbent or a feed solution containing a component easily causing tailing (a phenomenon in which concentration distribution becomes broad) is supplied to a circulation system, it is necessary to use a large amount of eluent for desorbing (removing) these components. Using of a large amount of eluent causes an increase in concentration cost of an extraction liquid and also leads to a decrease in production amount of a target purified product per adsorbent.

(5) On the other hand, in chromatographic separation by a simulated moving-bed scheme, use of two or more kinds of eluents has also been reported. For example, Patent Literature 2 describes that a first eluent having weak desorption strength and a second eluent having strong desorption strength are used and a timing for supplying these eluents and a feed solution and a timing for extracting a weakly adsorptive fraction, an intermediately adsorptive fraction, and a strongly adsorptive fraction are set as a specific combination, so that high separation performance is achieved with a small amount of adsorbent.

CITATION LIST

Patent Literatures

(6) Patent Literature 1: Japanese Patent No. 1998860 Patent Literature 2: Japanese Patent No. 4606092

SUMMARY OF THE INVENTION

Technical Problem

(7) The chromatographic separation of the simulated moving-bed scheme has been also studied on application to medical fields since a target substance to be purified can be continuously obtained at a high purity. For example, in production of antibody drugs, in an extract or culture solution of cultured cells producing antibodies, in addition to target antibodies, fragments, which have been generated by cleavage or the like of antibodies and do not function as antibodies, or aggregates, which are generated by aggregation of antibodies to become bulky, are generated. In general, the fragments have a few interaction sites with the adsorbent and weak adsorptive property with respect to the adsorbent. On the other hand, the aggregates have strong adsorptive property with respect to the adsorbent. Therefore, in the case of applying the chromatographic separation of the simulated moving-bed scheme to purification of antibody drugs, it is necessary to fractionate a target antibody as an intermediately adsorptive fraction showing intermediate adsorptive property with respect to the adsorbent. On the other hand, regarding a weakly adsorptive fraction and a strongly adsorptive fraction, it is necessary to sufficiently remove both of the fractions with a high removal rate.

(8) Furthermore, in the practical use of such chromatographic separation, it is also important that a necessary amount of adsorbent is reduced as much as possible to enhance separation treatment efficiency, and thereby cost reduction is achieved.

(9) However, the present inventors have conducted studies on chromatographic separation by a conventional simulated moving-bed scheme including the techniques described in respective patent literatures described above, and as a result, have found that the above objects are difficult to

sufficiently achieve.

(10) In this regard, the present invention provides a chromatographic separation method using a simulated moving-bed scheme capable of fractionating a purification target component in a feed solution at a high purity with a smaller amount of adsorbent used.

(11) Furthermore, the present invention also provides a chromatographic separation system suitable for implementing the above-described chromatographic separation method.

Solution to Problem

(12) The present inventors have conducted intensive studies in view of the above-described problems, and as a result, have found that the above-described problems can be solved by using two or more kinds of eluents and setting a feed solution supply port, a strongly adsorptive fraction extraction port, an intermediately adsorptive fraction extraction port, and a weakly adsorptive fraction extraction port to have a specified positional relationship in a circulation system in a chromatographic separation method using a simulated moving-bed scheme. The present inventors further intensively conducted studies based on these findings, and have completed the present invention.

(13) The above problems of the present invention have been solved by the following means.

(14) [1]

(15) A simulated moving-bed type chromatographic separation method including separating a weakly adsorptive component, a strongly adsorptive component, and an intermediately adsorptive component that has adsorptive property intermediate between the two components, with respect to an adsorbent, with two or more kinds of eluents by using a circulation system, the weakly adsorptive component, the strongly adsorptive component, and the intermediately adsorptive component being contained in a feed solution, wherein, in the circulation system, three or more unit packed columns each packed with the adsorbent are connected in series and in an endless form via pipes, wherein the circulation system is divided into three sections 1 to 3 provided, in an annularly continuous manner, from an upstream side to a downstream side while each section has at least one unit packed column, wherein a feed solution supply port F, two or more eluent supply ports D corresponding to the two or more kinds of eluents, an extraction port A of a weakly adsorptive fraction containing the weakly adsorptive component, an extraction port B of an intermediately adsorptive fraction containing the intermediately adsorptive component, and an extraction port C of a strongly adsorptive fraction containing the strongly adsorptive component are provided on the pipes of the circulation system, and positions of the feed solution supply port F, the extraction port A, the extraction port B, and the extraction port C are set as the following (a) to (c): (a) the extraction port B is provided on the downstream side of the feed solution supply port F with at least one section interposed therebetween; (b) the extraction port C is provided on the pipe having the feed solution supply port F or the extraction port C is provided on the upstream side of the feed solution supply port F with at least one section interposed therebetween; and (c) the extraction port A is provided on the pipe having the extraction port B or the extraction port A is provided on the downstream side of the extraction port B with at least one section interposed therebetween, and wherein the chromatographic separation method includes, in sequence and a repeated manner, the following steps (A) and (B): [step (A)] a step of simultaneously or separately supplying the feed solution from the feed solution supply port F and the two or more kinds of eluents from the two or more eluent supply ports D, respectively, and simultaneously or separately extracting the weakly adsorptive fraction from the extraction port A, the intermediately adsorptive fraction from the extraction port B, and the strongly adsorptive fraction from the extraction port C, respectively; and [step (B)] a step of shifting the feed solution supply port F, the eluent supply ports D, the extraction port A, the extraction port B, and the extraction port C to the downstream side, while maintaining a relative positional relationship therebetween after finishing the step (A).

[2]

(16) The simulated moving-bed type chromatographic separation method described in [1], wherein,

in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-8), (A2-8), (A3-8), and (A4-8): <sub-step (A1-8)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 3 as the extraction port A; <sub-step (A2-8)> supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 2 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1; <sub-step (A3-8)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying the eluent d-II from the eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying the eluent d-III from the eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2; <sub-step (A4-8)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 2 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

[3]

(17) The simulated moving-bed type chromatographic separation method described in [1], wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-9), (A2-9), (A3-9), and (A4-9): <sub-step (A1-9)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 3 as the extraction port A; <sub-step (A2-9)> supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 2 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1; <sub-step (A3-9)> supplying the eluent d-II from the eluent supply port D-II, supplying the eluent d-III from the eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the sections 1 and 2, and weakening desorption strength of the eluent passing through the section 3 more than the desorption

strength of the eluent passing through the sections 1 and 2; <sub-step (A4-9)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, supplying the eluent d-II from the eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

[4]

(18) The simulated moving-bed type chromatographic separation method described in [1], wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-10), (A2-10), (A3-10), and (A4-10): <sub-step (A1-10)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 3 as the extraction port A; <sub-step (A2-10)> supplying an eluent d-IV having desorption strength equal to or stronger than the feed solution from an eluent supply port D-IV while using an upstream end of the section 2 as the eluent supply port D-IV and extracting the weakly adsorptive fraction from the extraction port A; <sub-step (A3-10)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2; <sub-step (A4-10)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 2 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

[5]

(19) A simulated moving-bed type chromatographic separation method including separating a weakly adsorptive component, a strongly adsorptive component, and an intermediately adsorptive component that has adsorptive property intermediate between the two components, with respect to an adsorbent, with two or more kinds of eluents by using a circulation system, the weakly

adsorptive component, the strongly adsorptive component, and the intermediately adsorptive component being contained in a feed solution, wherein, in the circulation system, five or more unit packed columns each packed with the adsorbent are connected in series and in an endless form via pipes, wherein the circulation system is divided into five sections 1 to 5 provided, in an annularly continuous manner, from an upstream side to a downstream side while each section has at least one unit packed column, wherein a feed solution supply port F, two or more eluent supply ports D corresponding to the two or more kinds of eluents, an extraction port A of a weakly adsorptive fraction containing the weakly adsorptive component, an extraction port B of an intermediately adsorptive fraction containing the intermediately adsorptive component, and an extraction port C of a strongly adsorptive fraction containing the strongly adsorptive component are provided on the pipes of the circulation system, and positions of the feed solution supply port F, the extraction port A, the extraction port B, and the extraction port C are set as the following (a) to (c): (a) the extraction port B is provided on the downstream side of the feed solution supply port F with at least one section interposed therebetween; (b) the extraction port C is provided on the pipe having the feed solution supply port F or the extraction port C is provided on the upstream side of the feed solution supply port F with at least one section interposed therebetween; and (c) the extraction port A is provided on the pipe having the extraction port B or the extraction port A is provided on the downstream side of the extraction port B with at least one section interposed therebetween, and wherein the chromatographic separation method includes, in sequence and a repeated manner, the following steps (A) and (B): [step (A)] a step of simultaneously or separately supplying the feed solution from the feed solution supply port F and the two or more kinds of eluents from the two or more eluent supply ports D, respectively, and simultaneously or separately extracting the weakly adsorptive fraction from the extraction port A, the intermediately adsorptive fraction from the extraction port B, and the strongly adsorptive fraction from the extraction port C, respectively; and [step (B)] a step of shifting the feed solution supply port F, the eluent supply ports D, the extraction port A, the extraction port B, and the extraction port C to the downstream side, while maintaining a relative positional relationship therebetween after finishing the step (A).

[6]

(20) The simulated moving-bed type chromatographic separation method described in [5], wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-11), (A2-11), and (A3-11): <sub-step (A1-11)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 5 as the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 3, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3; <sub-step (A2-11)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying the eluent d-III from the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3; and <sub-step (A3-11)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the

intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 3 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

[7]

(21) The simulated moving-bed type chromatographic separation method described in [5], wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-12), (A2-12), (A3-12), and (A4-12): <sub-step (A1-12)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 5 as the extraction port A; <sub-step (A2-12)> supplying an eluent d-IV having desorption strength equal to or stronger than the feed solution from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV and extracting the weakly adsorptive fraction from the extraction port A; <sub-step (A3-12)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3; and <sub-step (A4-12)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 3 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

(22) In the present specification, the terms “upstream” and “downstream” are used with respect to the flow direction of fluid in the circulation system. That is, the term “upstream side” with respect to a certain part in the circulation system means a side on which the fluid flows toward the part, and the term “downstream side” means a side on which the fluid flows out from the part.

(23) In the present specification, the term “strongly adsorptive component” means a component having strong adsorption force with respect to an adsorbent for a plurality of components contained in a feed solution, the term “weakly adsorptive component” means a component having weak adsorption force with respect to the adsorbent for the plurality of components contained in the feed solution, and the term “intermediately adsorptive component” means a component having weaker adsorption force with respect to the adsorbent than the strongly adsorptive component and having stronger adsorption force with respect to the adsorbent than the weakly adsorptive component. That

is, the terms “strongly adsorptive”, “intermediately adsorptive”, and “weakly adsorptive” indicate the relative adsorption force when comparing adsorption force of each component contained in the feed solution with respect to the adsorbent.

(24) The above-described “strongly adsorptive component”, “intermediately adsorptive component”, and “weakly adsorptive component” may each be composed of a single component or a plurality of components. Furthermore, the plurality of components may have the same or different adsorption force.

(25) Grouping of respective components in the feed solution into the “strongly adsorptive component”, the “intermediately adsorptive component”, and the “weakly adsorptive component” can be appropriately set depending on purposes. When a case where the feed solution contains four kinds of components is used as an example, two kinds of components in descending order according to adsorption force with respect to the adsorbent can be collectively regarded as the strongly adsorptive component, a component having the third strongest adsorption force with respect to the adsorbent can be regarded as the intermediately adsorptive component, and a component having the weakest adsorption force with respect to the adsorbent can be regarded as the weakly adsorptive component. Furthermore, a component having the strongest adsorption force with respect to the adsorbent can also be regarded as the strongly adsorptive component, a component having the second strongest adsorption force and a component having the third strongest adsorption force with respect to the adsorbent can also be collectively regarded as the intermediately adsorptive component, and a component having the weakest adsorption force with respect to the adsorbent can also be regarded as the weakly adsorptive component. Furthermore, a component having the strongest adsorption force with respect to the adsorbent can also be regarded as the strongly adsorptive component, a component having the second strongest adsorption force with respect to the adsorbent can also be regarded as the intermediately adsorptive component, and a component having the third strongest adsorption force with respect to the adsorbent and a component having the weakest adsorption force with respect to the adsorbent can also be collectively regarded as the weakly adsorptive component. The same applies to a case where the feed solution contains five or more kinds of components. They can be separated and purified on the basis of such grouping.

(26) In the present invention, the term “desorption strength” of the eluent means a strength of effect of desorbing a component adsorbed on an adsorbent from the adsorbent.

Advantageous Effects of Invention

(27) According to the simulated moving-bed type chromatographic separation method of the present invention, a purification target component in a feed solution can be fractionated at a high purity while the amount of an adsorbent used is suppressed. Furthermore, the simulated moving-bed type chromatographic separation system of the present invention can be suitably used for implementing the simulated moving-bed type chromatographic separation method of the present invention.

Description

BRIEF DESCRIPTION OF DRAWINGS

(1) FIG. 1 is a system diagram illustrating an example of a simulated moving-bed type chromatographic separation system of the present invention.

(2) FIG. 2 is a flow diagram of respective sub-steps constituting the step (A) in an embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(3) FIG. 3 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 2 is finished and then the step (B) is carried out.

(4) FIG. 4 is a flow diagram of respective sub-steps constituting the step (A) in another

embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(5) FIG. 5 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 4 is finished and then the step (B) is carried out.

(6) FIG. 6 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(7) FIG. 7 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 6 is finished and then the step (B) is carried out.

(8) FIG. 8 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(9) FIG. 9 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 8 is finished and then the step (B) is carried out.

(10) FIG. 10 is a flow diagram showing operation steps of a single column step gradient in Comparative Examples 1 and 2.

(11) FIG. 11 is a flow diagram illustrating operation steps of simulated moving-phase type chromatographic separation in Comparative Example 3.

(12) FIG. 12 is a flow diagram illustrating operation steps of simulated moving-phase type chromatographic separation in Comparative Example 4.

(13) FIG. 13 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(14) FIG. 14 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 13 is finished and then the step (B) is carried out.

(15) FIG. 15 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(16) FIG. 16 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 15 is finished and then the step (B) is carried out.

(17) FIG. 17 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(18) FIG. 18 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 17 is finished and then the step (B) is carried out.

(19) FIG. 19 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(20) FIG. 20 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 19 is finished and then the step (B) is carried out.

(21) FIG. 21 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(22) FIG. 22 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 21 is finished and then the step (B) is carried out.

(23) FIG. 23 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(24) FIG. 24 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 23 is finished and then the step (B) is carried out.

(25) FIG. 25 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(26) FIG. 26 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 25 is finished and then the step (B) is carried out.

(27) FIG. 27 is a flow diagram of respective sub-steps constituting the step (A) in still another embodiment of the simulated moving-bed type chromatographic separation method of the present invention.

(28) FIG. 28 is a flow diagram of respective sub-steps constituting the step (A) after the step (A) shown in FIG. 27 is finished and then the step (B) is carried out.

DESCRIPTION OF EMBODIMENTS

(29) Preferred embodiments of a simulated moving-bed type chromatographic separation method of the present invention (hereinafter, also simply referred to as the “method of the present invention”) will be described.

(30) The method of the present invention is carried out by using a circulation system in which a plurality of unit packed columns each packed with an adsorbent are connected in series and in an endless form via pipes. The circulation system itself used in the simulated moving-bed scheme is publicly known, and for example, JP-A-2009-36536 (“JP-A” means an unexamined published Japanese patent application), Japanese Patent No. 4606092 B2, and the like can be referred to.

(31) The circulation system will be described below using the drawings; however, the present invention is not limited to these embodiments, except for the requirements defined by the present invention.

(32) Incidentally, the drawings described below are explanatory diagrams for facilitating understanding of the present invention, and regarding sizes and relative magnitude relationships of respective configurations, the large one or the small one is sometimes changed for the purpose of illustration, and the form does not show a real relation as it is. Furthermore, the present invention is not limited to shapes, relative positional relationships, and the like illustrated in these drawings, except for the requirements defined by the present invention.

(33) Furthermore, conditions other than the requirements defined by the present invention, such as the capacity of a unit packed column, intratubular cross-sectional areas and lengths of pipes, and a flow velocity of a liquid to be supplied to the circulation system, can be appropriately set depending on purposes.

(34) A preferred embodiment of a circulation system used in the method of the present invention is illustrated in FIG. 1. A circulation system 100 illustrated in FIG. 1 includes four unit packed columns (columns) (unit packed columns 10a, 10b, 10c, and 10d) packed with an adsorbent Ab, an exit of each unit packed column is connected to an entrance of an adjacent unit packed column via a pipe 1, and respective unit packed columns are connected in series as a whole.

(35) Further, all of the unit packed columns are connected in an endless form (in an annular form) by connecting the exit of a most downstream-side unit packed column (for example, the unit packed column 10d) to the entrance of a most upstream-side unit packed column (for example, the unit packed column 10a) via the pipe 1. With such a configuration, a fluid can be circulated in the circulation system 100. The unit packed columns 10a to 10d may be the same as or different from each other in the inner shape, the size, and the amount of the adsorbent packed. It is preferable to use the unit packed columns 10a to 10d of which the inner shape, size, and the amount of the adsorbent packed are all equivalent (preferably are the same).

(36) A circulation pump P1 for allowing a fluid to flow in an arrow direction can be arranged in the circulation system 100. The circulation pump P1 is preferably a metering pump. Furthermore, in the circulation system 100, shutoff valves R1, R2, R3, and R4 capable of shutting off the circulation of the fluid to the unit packed column on the downstream side of the pipe 1 are provided on the pipe 1 between two adjacent unit packed columns.

(37) Weakly adsorptive fraction extracting lines **2a**, **2b**, **2c**, and **2d** for extracting a fraction containing much weakly adsorptive components with respect to the adsorbent **Ab** (referred to as “weakly adsorptive fraction with respect to the adsorbent **Ab**” or simply referred to as “weakly adsorptive fraction” in the present specification) are divergently arranged between the respective shutoff valves **R1** to **R4** and the exits of the respective unit packed columns **10a** to **10d** positioned at the upstream sides thereof, respectively. Weakly adsorptive fraction extracting valves **A1**, **A2**, **A3**, and **A4** capable of opening and closing the respective weakly adsorptive fraction extracting lines are provided on the respective weakly adsorptive fraction extracting lines **2a**, **2b**, **2c**, and **2d**, respectively. The respective weakly adsorptive fraction extracting lines **2a**, **2b**, **2c**, and **2d** are joined into a single weakly adsorptive fraction joining pipe **2J**.

(38) Furthermore, similarly, intermediately adsorptive fraction extracting lines **3a**, **3b**, **3c**, and **3d** for extracting a fraction containing much intermediately adsorptive components with respect to the adsorbent **Ab** (referred to as “intermediately adsorptive fraction with respect to the adsorbent **Ab**” or simply referred to as “intermediately adsorptive fraction” in the present specification) are divergently arranged between the respective shutoff valves **R1** to **R4** and the exits of the respective unit packed columns **10a** to **10d** positioned at the upstream sides thereof. Intermediately adsorptive fraction extracting valves **B1**, **B2**, **B3**, and **B4** capable of opening and closing the respective intermediately adsorptive fraction extracting lines are provided on the respective intermediately adsorptive fraction extracting lines **3a**, **3b**, **3c**, and **3d**, respectively. The respective intermediately adsorptive fraction extracting lines **3a**, **3b**, **3c**, and **3d** are joined into a single intermediately adsorptive fraction joining pipe **3J**.

(39) Furthermore, similarly, strongly adsorptive fraction extracting lines **4a**, **4b**, **4c**, and **4d** for extracting a fraction containing much strongly adsorptive components with respect to the adsorbent **Ab** (referred to as “strongly adsorptive fraction with respect to the adsorbent **Ab**” or simply referred to as “strongly adsorptive fraction” in the present specification) are divergently arranged between the respective shutoff valves **R1** to **R4** and the exits of the respective unit packed columns **10a** to **10d** positioned at the upstream sides thereof. Strongly adsorptive fraction extracting valves **C1**, **C2**, **C3**, and **C4** capable of opening and closing the respective strongly adsorptive fraction extracting lines are provided on the respective strongly adsorptive fraction extracting lines **4a**, **4b**, **4c**, and **4d**, respectively. The respective strongly adsorptive fraction extracting lines **4a**, **4b**, **4c**, and **4d** are joined into a single strongly adsorptive fraction joining pipe **4J**.

(40) In a step (A) described below, some of the weakly adsorptive fraction extracting valves **A1**, **A2**, **A3**, and **A4** is in a state of being opened. A connection part between the weakly adsorptive fraction extracting line in which the opened weakly adsorptive fraction extracting valve is provided and the pipe **1** becomes an extraction port A of a weakly adsorptive fraction in the step (A) described below.

(41) Furthermore, in the step (A) described below, some of the intermediately adsorptive fraction extracting valves **B1**, **B2**, **B3**, and **B4** is in a state of being opened. A connection part between the intermediately adsorptive fraction extracting line in which the opened intermediately adsorptive fraction extracting valve is provided and the pipe **1** becomes an extraction port B of an intermediately adsorptive fraction in the step (A) described below.

(42) Furthermore, in the step (A) described below, some of the strongly adsorptive fraction extracting valves **C1**, **C2**, **C3**, and **C4** is in a state of being opened. A connection part between the strongly adsorptive fraction extracting line in which the opened strongly adsorptive fraction extracting valve is provided and the pipe **1** becomes an extraction port C of a strongly adsorptive fraction in the step (A) described below.

(43) A safety valve (or a relief valve) (not illustrated) can be provided in an appropriate part in the circulation system **100** in order to prevent the pressure of the circulation system **100** from being excessively increased. Furthermore, check valves **T1**, **T2**, **T3**, and **T4** for backflow prevention are preferably provided between two adjacent unit packed columns.

(44) As illustrated in FIG. 1, the inside of the circulation system **100** is configured to capable of supplying a feed solution **7** housed in a feed solution tank **6**. Further, the inside of the circulation system **100** is configured to capable of supplying two or more kinds of eluents. In FIG. 1, as an example, an embodiment in which four kinds of eluents are supplied is illustrated.

(45) The feed solution **7** is supplied by a feed solution supply pump **P2** capable of controlling the supply flow rate via a feed solution supplying line **11**. The feed solution supply pump **P2** is preferably a metering pump. The feed solution supplying line **11** is diverged into four divergent feed solution supplying lines **11a**, **11b**, **11c**, and **11d** as illustrated in FIG. 1, and is configured to capable of supplying the feed solution to the entrances of the respective unit packed columns **10a**, **10b**, **10c**, and **10d** via the respective divergent feed solution supplying lines **11a**, **11b**, **11c**, and **11d**. Feed solution supplying valves **F1**, **F2**, **F3**, and **F4** capable of being opened/closed are provided in the respective divergent feed solution supplying lines **11a**, **11b**, **11c**, and **11d**, and the feed solution is supplied through a divergent feed solution supplying line having an opened feed solution supplying valve to a unit packed column connected to the downstream thereof.

(46) In the step (A) described below, some of the feed solution supplying valves **F1**, **F2**, **F3**, and **F4** is in a state of being opened. A connection part between the divergent feed solution supplying line in which the opened feed solution supplying valve is provided and the pipe **1** becomes a feed solution supply port **F** in the step (A) described below.

(47) FIG. 1 illustrates an embodiment in which four kinds of eluents each having different desorption strength are supplied. An eluent **9a** housed in an eluent tank **8a** is supplied to an eluent supplying line **12** by an eluent supply pump **P3** capable of controlling the supply flow rate. An eluent **9b** housed in an eluent tank **8b** is supplied to an eluent supplying line **13** by an eluent supply pump **P4** capable of controlling the supply flow rate. An eluent **9c** housed in an eluent tank **8c** is supplied to an eluent supplying line **14** by an eluent supply pump **P5** capable of controlling the supply flow rate. Further, an eluent **9d** housed in an eluent tank **8d** is supplied to an eluent supplying line **15** by an eluent supply pump **P6** capable of controlling the supply flow rate.

(48) The eluent supply pumps **P3** to **P6** are each preferably a metering pump. The eluent supplying line **12** is diverged into four divergent eluent supplying lines **12a**, **12b**, **12c**, and **12d** as illustrated in FIG. 1, and is configured to be capable of supplying the eluents to the entrances of the respective unit packed columns **10a**, **10b**, **10c**, and **10d** via the respective divergent eluent supplying lines **12a**, **12b**, **12c**, and **12d**. Eluent supplying valves **E1a**, **E2a**, **E3a**, and **E4a** capable of being opened/closed are provided in the respective divergent eluent supplying lines **12a**, **12b**, **12c**, and **12d**, and the eluent is supplied through a divergent eluent supplying line having an opened eluent supplying valve to a unit packed column connected to the downstream thereof.

(49) Similarly, the eluent supplying line **13** is diverged into four divergent eluent supplying lines **13a**, **13b**, **13c**, and **13d**, the eluent supplying line **14** is diverged into four divergent eluent supplying lines **14a**, **14b**, **14c**, and **14d**, the eluent supplying line **15** is diverged into four divergent eluent supplying lines **15a**, **15b**, **15c**, and **15d**, and each eluent supplying line is configured to capable of supplying each eluent to the entrances of the respective unit packed columns **10a**, **10b**, **10c**, and **10d**.

(50) Eluent supplying valves **E1b**, **E2b**, **E3b**, and **E4b** capable of being opened/closed are provided in the divergent eluent supplying lines **13a**, **13b**, **13c**, **13d**, eluent supplying valves **E1c**, **E2c**, **E3c**, and **E4c** capable of being opened/closed are provided in the divergent eluent supplying lines **14a**, **14b**, **14c**, and **14d**, and eluent supplying valves **E1d**, **E2d**, **E3d**, and **E4d** capable of being opened/closed are provided in the divergent eluent supplying lines **15a**, **15b**, **15c**, and **15d**, respectively.

(51) In the step (A) described below, a connection part between the divergent eluent supplying line in which the opened eluent supplying valve is provided and the pipe **1** becomes an eluent supply port **D**. In the method of the present invention, since two or more kinds of eluents are used, in the step (A) described below, there are a plurality of eluent supplying valves to be opened. Therefore,

in the step (A) described below, the eluent supply port D exists by the number (two or more) corresponding to the kinds of eluent to be used.

(52) Subsequently, the operation of the circulation system when the method of the present invention is carried out by the circulation system will be described; however, the present invention is not limited to these embodiments, except for the requirements defined by the present invention.

(53) In the method of the present invention, the circulation system is set such that positions of the feed solution supply port F, the extraction port A of a weakly adsorptive fraction, the extraction port B of an intermediately adsorptive fraction, and the extraction port C of a strongly adsorptive fraction have relationship satisfying the following (a) to (c). That is, in repetition of steps (A) and (B) described below, the relative positional relationship between the feed solution supply port F, the extraction port A of a weakly adsorptive fraction, the extraction port B of an intermediately adsorptive fraction, and the extraction port C of a strongly adsorptive fraction satisfies (a) to (c) at all times.

(54) (a) The intermediately adsorptive fraction extraction port B is provided on the downstream side of the feed solution supply port F with at least one unit packed column (at least one section) interposed therebetween.

(55) (b) The strongly adsorptive fraction extraction port C is provided on the pipe having the feed solution supply port F or the strongly adsorptive fraction extraction port C is provided on the upstream side of the feed solution supply port F with at least one unit packed column (at least one section) interposed therebetween.

(56) Herein, the expression “the strongly adsorptive fraction extraction port C is provided on the pipe having the feed solution supply port F” means that any unit packed column is not arranged between the strongly adsorptive fraction extraction port C and the feed solution supply port F.

(57) Furthermore, in a case where “the strongly adsorptive fraction extraction port C is provided on the pipe having the feed solution supply port F”, the strongly adsorptive fraction extraction port C is provided upstream in the same pipe than the feed solution supply port F. This is applicable to all of the relationships between the extraction ports and the supply ports provided on the same pipes. That is, in the circulation system, in a certain extraction port and a certain supply port are provided on the same pipe (in a case where an extraction port and a supply port are provided without a unit packed column interposed therebetween), the extraction port is provided upstream in the same pipe than the supply port. This is to prevent the supplied liquid from being extracted from the extraction port before the liquid reaches the unit packed column on the downstream thereof.

(58) The above (b) is preferably an embodiment in which the strongly adsorptive fraction extraction port C is provided on the upstream side of the feed solution supply port F with at least one unit packed column (at least one section) interposed therebetween.

(59) (c) The weakly adsorptive fraction extraction port A is provided on the pipe having the intermediately adsorptive fraction extraction port B or the weakly adsorptive fraction extraction port A is provided on the downstream side of the intermediately adsorptive fraction extraction port B with at least one unit packed column (at least one section) interposed therebetween.

(60) Herein, the expression “the weakly adsorptive fraction extraction port A is provided on the pipe having the intermediately adsorptive fraction extraction port B” means that any unit packed column is not arranged between the weakly adsorptive fraction extraction port A and the intermediately adsorptive fraction extraction port B.

(61) The above (c) is preferably an embodiment in which the weakly adsorptive fraction extraction port A is provided on the downstream side of the intermediately adsorptive fraction extraction port B with at least one unit packed column (at least one section) interposed therebetween.

(62) In the method of the present invention, the following steps (A) and (B) are sequentially repeated by using the circulation system.

(63) [Step (A)]

(64) Step of simultaneously or separately supplying the feed solution from the feed solution supply

port F and the two or more kinds of eluents from the two or more eluent supply ports D, respectively, and simultaneously or separately extracting a weakly adsorptive fraction from the weakly adsorptive fraction extraction port A, an intermediately adsorptive fraction from the intermediately adsorptive fraction extraction port B, and a strongly adsorptive fraction from the strongly adsorptive fraction extraction port C, respectively.

(65) Herein, in the step (A), the total of the amount of the feed solution supplied from the feed solution supply port F and the amount of the eluent supplied from the eluent supply port D coincides with the total of the amount of the weakly adsorptive fraction extracted from the weakly adsorptive fraction extraction port A, the amount of the intermediately adsorptive fraction extracted from the intermediately adsorptive fraction extraction port B, and the amount of the strongly adsorptive fraction C extracted from the strongly adsorptive fraction extraction port C. That is, in a state where the liquid is supplied into the circulation system, the same amount of the liquid as the amount of the liquid supplied is extracted from the inside of the circulation system.

(66) More specifically, in a case where a liquid is supplied from a certain supply port (X) and the liquid is extracted from an extraction port (Y) on the downstream side thereof, when the liquid is not supplied from the downstream side of X and the upstream side of Y, the amount of the liquid extracted from Y is the same as the amount of the liquid supplied from X. Furthermore, when the liquid is supplied from the downstream side of X and the upstream side of Y, the amount of the liquid extracted from Y is the same as the total of the amount of the liquid supplied from X and the amount of the liquid supplied from the downstream side of X and the upstream side of Y. For example, in the sub-step (A1-1) of FIG. 2, the supplied amount of the eluent supplied from the eluent supply port D1 is the same as the extracted amount of the strongly adsorptive fraction extracted from the strongly adsorptive fraction extraction port C. Furthermore, similarly, in the sub-step (A1-1), the total of the supplied amount of the eluent supplied from the eluent supply port D2 and the supplied amount of the feed solution supplied from the feed solution supply port F is the same as the amount of the weakly adsorptive fraction extracted from the weakly adsorptive fraction extraction port A.

(67) Furthermore, the expression “simultaneously or separately supplying” means that a liquid is supplied without time differences (without delaying of the supply timing) or is supplied with time differences (with delaying of the supply timing). However, in one step (A), in a case where two or more supply ports supplying two or more kinds of liquids are arranged in the same pipe (in a case where two or more supply ports are arranged in the pipe without a unit packed column interposed therebetween, and different liquids are supplied from each of the two or more supply ports), the supplies of the two or more kinds of liquids are not simultaneously performed. That is, in one step (A), the supplies of the two or more kinds of liquids are performed as different sub-steps. Similarly, in one step (A), in a case where two or more extraction ports extracting two or more kinds of fractions are arranged in the same pipe (in a case where two or more extraction ports are arranged in the pipe without a unit packed column interposed therebetween, and different fractions are extracted from each of the two or more extraction ports), the extractions of the two or more kinds of fractions are not simultaneously performed. That is, in one step (A), the extractions of the two or more kinds of fractions are performed as different sub-steps.

(68) [Step (B)]

(69) Step of shifting the feed solution supply port F, the eluent supply ports D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C to the downstream side, while maintaining a relative positional relationship therebetween, after finishing the step (A).

(70) This shifting to the downstream side means that the feed solution supply port F, the eluent supply ports D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted by one unit packed column to the downstream side while the relative positional relationship therebetween

is maintained.

(71) For example, in the step (A), in a case where a connection part between the divergent feed solution supplying line in which the feed solution supplying valve F1 is provided and the pipe 1 is the feed solution supply port F, this feed solution supply port F is shifted to a connection part between the divergent feed solution supplying line in which the feed solution supply valve F2 is provided and the pipe 1 by the step (B). The same applies to the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C. Furthermore, shifting of each supply port and each extraction port to the downstream side by one unit packed column can be performed by regulating opening/closing various pumps or various valves arranged in the circulation system.

(72) As a result of carrying out the step (B), in the subsequent step (A) (referred to as the step (A2)), supply and extraction of a liquid are performed with respect to each unit packed column on the downstream side than the step (A1) by one unit packed column. The supply and extraction of a liquid are performed similarly to the case where supply and extraction of a liquid are performed with respect to each unit packed column in the step (A) (referred to as the step (A1)) immediately before the step (B).

(73) The step (A) is preferably configured by a plurality of sub-steps. In this case, it is possible to appropriately arrange in which sub-steps the feed solution is supplied from the feed solution supply port F, each eluent of two or more kinds of eluents is supplied from the two or more eluent supply ports D, the weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction is extracted from the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, depending on purposes and in the range that the effects of the present invention are not impaired.

(74) In particular, in the method of the present invention, the step (A) preferably includes a sub-step of supplying a feed solution and a sub-step of not supplying a feed solution. That is, it is preferable that there are a time at which a feed solution is supplied and a time at which a feed solution is not supplied in the step (A).

(75) In the step (A), two or more kinds of eluents are supplied. A supply port of an eluent having the strongest desorption strength of these two or more kinds of eluents is preferably provided on a pipe on the upstream side with respect to the strongly adsorptive fraction extraction port C with the unit packed column interposed therebetween. The remaining supply port of the eluent and the feed solution supply port are preferably provided on the same pipe as that for the supply port of the eluent having the strongest desorption strength or provided further upstream than the supply port of the eluent having the strongest desorption strength with the unit packed column interposed therebetween. The expression “provided on the same pipe as that for the supply port of the eluent having the strongest desorption strength or provided further upstream than the supply port of the eluent having the strongest desorption strength with the unit packed column interposed therebetween” means that a supply port of an eluent other than the strongest eluent or a feed solution supply port is provided on any pipes in the range which begins at the pipe in which the supply port of the strongest eluent is provided, extends toward the upstream side, and ends at the pipe in which the strongly adsorptive fraction extraction port C is provided (in other words, means that a supply port of an eluent other than the strongest eluent or a feed solution supply port is provided on any pipes in the range which begins at the pipe in which the strongly adsorptive fraction extraction port C is provided, extends toward the downstream side, and ends at the pipe in which the supply port of the strongest eluent is provided; further, in other words, in a case where two or more unit packed columns are provided between the supply port of the strongest eluent and the strongly adsorptive fraction extraction port C, a supply port of an eluent or a feed solution supply port is not provided on the pipes connecting the two or more unit packed columns). In this case, in a case where eluents other than the strongest eluent are two or more kinds, some of two or

more supply ports corresponding thereto may be provided on the same pipe and each of the supply ports may be provided on a separate pipe with the unit packed column interposed therebetween. Furthermore, supply ports of eluents other than the strongest eluent and the feed solution supply port may be provided on the same pipe.

(76) Incidentally, providing one supply port of supply ports of eluents other than the eluent having the strongest desorption strength in the same pipe as that for the supply port of the eluent having the strongest desorption strength is a preferred embodiment of the present invention.

(77) In the step (A), during the eluent having the strongest desorption strength of two or more kinds of eluents is supplied, an embodiment in which the same amount of a strongly adsorptive fraction as the supplied amount of the eluent having the strongest desorption strength is extracted from the downstream thereof is preferably employed. In this case, an embodiment in which at least one unit packed column is arranged between the supply port of the eluent having the strongest desorption strength and the strongly adsorptive fraction extraction port on the downstream thereof and other supply ports do not exist therebetween is preferably employed.

(78) In the step (A), it is preferable to provide a time interval (sub-step) in which the same amount of an intermediately adsorptive fraction as the supplied amount of the eluent having the second strongest desorption strength is extracted from the downstream thereof while the eluent having the second strongest desorption strength of two or more kinds of eluents is supplied. In this case, at least one unit packed column (preferably, a plurality of unit packed columns) is arranged between the supply port of the eluent having the second strongest desorption strength and the intermediately adsorptive fraction extraction port on the downstream thereof. Furthermore, even if other supply ports exist between the pipe in which the supply port of the eluent having the second strongest desorption strength is provided and the pipe in which the intermediately adsorptive fraction extraction port on the downstream side thereof is provided, a liquid is not supplied from the other supply ports in the time interval in which the intermediately adsorptive fraction is extracted.

(79) During carrying out the step (A), it is preferable to extract the weakly adsorptive fraction at all times. Therefore, even in a case where the step (A) is configured by a plurality of sub-steps, it is preferable to extract the weakly adsorptive fraction in the plurality of sub-steps at all times.

(80) In the method of the present invention, it is preferable to use three or more kinds of eluents each having different desorption strength, more preferable to use four or more kinds of eluents each having different desorption strength, further preferable to use four to six kinds of eluents each having different desorption strength, and particularly preferable to use four or five kinds of eluents each having different desorption strength.

(81) The type of eluents is not particularly limited and is appropriately set by a relationship with the type of adsorbents or the type of components in a feed solution. For example, in the case of using an ion-exchange resin as an adsorbent, a plurality of eluents each having different desorption strength can be prepared by changing the salt concentration of the eluent. For example, in the case of using a cation-exchange resin, a plurality of eluents having changed NaCl concentrations can be used as two or more kinds of eluents.

(82) Preferred embodiments of combinations of sub-steps in the step (A) will be described below. These embodiments can be performed by using the system of FIG. 1 or a system capable of carrying out a target embodiment conforming to the system of FIG. 1. Furthermore, the embodiments described below are merely examples of the present invention, and for example, from the viewpoint of relative desorption strength, two or more kinds of eluents positioned as an eluent d-1 described below can be prepared, and the kind of the eluent d-1 to be used can also be changed between sub-steps of supplying the eluent d-1. The same applies to the eluents d-II to d-V.

(83) That is, regarding the “eluent d-1” in an embodiment of the present invention, in the case of using the “eluent d-1” in different sub-steps in the embodiment, the “eluents d-1” used in different sub-steps may be the same as or different from each other. The same applies to the eluents d-II to d-V.

Embodiment 1

(84) In Embodiment 1, a circulation system having four or more unit packed columns is used. Here, it is assumed that this circulation system is divided into four sections 1 to 4 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(85) In this Embodiment 1, the following sub-steps (A1-1), (A2-1), and (A3-1) are performed in the step (A).

(86) In the present invention, the expression “sub-steps X, Y, and Z are performed in the step (A)” means that the step (A) includes the sub-steps X, Y, and Z, and the order for performing the sub-steps X, Y, and Z can be appropriately set in the range that the effects of the present invention are not impaired. In addition, the step (A) may include another sub-step(s) other than the sub-steps X, Y, and Z.

(87) As an embodiment in which “the sub-steps X, Y, and Z are performed in the step (A)”, typically, an embodiment in which the sub-steps X, Y, and Z are performed in order as the step (A) is exemplified, but the present invention is not limited to this embodiment. That is, the expression “the sub-steps X, Y, and Z are performed in step (A)” is not limited to an embodiment in which the sub-step Y is performed immediately after the sub-step X, the sub-step Z is performed immediately after the sub-step Y, the step (B) is performed immediately after the sub-step Z, and the sub-step X is performed immediately after the step (B). For example, in the embodiment including other the sub-steps, other sub-steps (sub-steps other than the sub-steps X, Y and Z) may be incorporated at least one of before the sub-step X (between the step (B) and the sub-step X), between the sub-steps X and Y, between the sub-steps Y and Z, or between the sub-step Z and the step (B) to the extent that the effects of the present invention are not impaired. There is a case where a target effect is obtainable even by incorporating additional sub-steps other than the sub-steps X, Y, and Z by adjustment of a supply flow rate, a flow velocity, eluent strength, or the like, and this can be easily understood by those skilled in the art who pertain to the present specification.

(88) <Sub-Step (A1-1)>

(89) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, a feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 4 as the weakly adsorptive fraction extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 3 and 4 more than the desorption strength of the eluent passing through the section 2.

(90) In the sub-step (A1-1), the supply of each liquid and the extraction of each fraction described above are continuously performed (that is, in the sub-step (A1-1), at all times, all of the supply of each liquid and the extraction of each fraction described above are performed without intermission). The same applies to each sub-step described hereinafter.

(91) Furthermore, in the present invention and the present specification, the description of the strength level of desorption strength of the eluent described in each sub-step corresponds to the description of the strength level of desorption strength of the eluent in the relevant sub-step but does not correspond to the description of the strength level of desorption strength of the eluent in different sub-steps. For example, in a case where the desorption strength of the eluent passing

through the section 1 is described as strongest in one sub-step constituting the step (A) and the desorption strength of the eluent passing through the section 1 is described as strongest in another sub-step constituting the step (A), the desorption strength of the eluent passing through the section 1 in the one sub-step and the desorption strength of the eluent passing through the section 1 in another sub-step may be the same as or different from each other.

(92) <Sub-Step (A2-1)>

(93) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 3 and 4 more than the desorption strength of the eluent passing through the section 2.

(94) The eluent supply port D-III in this sub-step (A2-1) is provided on the same pipe as that for the feed solution supply port F in the sub-step (A1-1).

(95) <Sub-Step (A3-1)>

(96) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 4 more than the desorption strength of the eluent passing through the sections 2 and 3.

(97) The desorption strength of the eluent passing through the sections 3 and 4 in the sub-step (A2-1) is also preferably equal to the desorption strength of the eluent passing through the section 4 in the sub-step (A3-1).

(98) As an example of the sub-step (A1-1), a sub-step of performing the following sub-step (A1-1ex) is mentioned, but the sub-step (A1-1) is not limited to the sub-step (A1-1ex).

(99) <Sub-Step (A1-1ex)>

(100) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 4 as the weakly adsorptive fraction extraction port A.

(101) As an example of the sub-step (A2-1), a sub-step of performing the following sub-step (A2-1ex) is mentioned, but the sub-step (A2-1) is not limited to the sub-step (A2-1ex).

(102) <Sub-Step (A2-1ex)>

(103) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the

eluent supply port D2, an eluent d3 having the weakest desorption strength of four kinds of eluents from an eluent supply port D3 while using an upstream end of the section 3 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(104) The eluent supply port D3 in this sub-step (A2-1ex) is provided on the same pipe as that for the feed solution supply port F in the sub-step (A1-1).

(105) As an example of the sub-step (A3-1), a sub-step of performing the following sub-step (A3-1ex) is mentioned, but the sub-step (A3-1) is not limited to the sub-step (A3-1ex).

(106) <Sub-Step (A3-1ex)>

(107) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents from an eluent supply port D4 while using an upstream end of the section 4 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(108) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-1ex), (A2-1ex), and (A3-1ex) are sequentially performed in the step (A) is illustrated in FIG. 2. In FIG. 2, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column (the number is given in order from left).

(109) After the step (A) in which the sub-steps (A1-1ex), (A2-1ex), and (A3-1ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-1ex), (A2-1ex), and (A3-1ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 3. The unit packed column arranged in each section illustrated in FIG. 2 is shifted to the downstream side one by one in FIG. 3. In this case, a process in which the step (A) illustrated in FIG. 2 is started and then the step (B) is performed is designated as one set, this process is performed for four sets, and it returns to the embodiment illustrated in FIG. 2 again.

Embodiment 2

(110) Similarly to Embodiment 1, also in Embodiment 2, a circulation system having four or more unit packed columns is used. Here, it is assumed that this circulation system is divided into four sections 1 to 4 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(111) In this Embodiment 2, the following sub-steps (A1-2), (A2-2), and (A3-2) are sequentially performed as the step (A).

(112) <Sub-Step (A1-2)>

(113) An eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, a feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 4 as the weakly adsorptive fraction extraction port A, thereby most strengthening desorption strength of the eluent passing through the sections 1 and 2, and weakening desorption strength of the eluent passing through the sections 3 and 4 more than the desorption strength of the eluent passing through the sections 1 and 2.

<Sub-Step (A2-2)>

(114) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 3 and 4 more than the desorption strength of the eluent passing through the section 2.

(115) The eluent supply port D-I in this sub-step (A2-2) is provided on the same pipe as that for the eluent supply port D-II in the sub-step (A1-2). Furthermore, the eluent supply port D-III is provided on the same pipe as that for the feed solution supply port F.

(116) The desorption strength of the eluent passing through the section 1 in the sub-step (A2-2) is preferably stronger than the desorption strength of the eluent passing through the section 1 in the sub-step (A1-2).

(117) <Sub-Step (A3-2)>

(118) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II in the sub-step (A2-2), an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 4 more than the desorption strength of the eluent passing through the sections 2 and 3.

(119) As an example of the sub-step (A1-2), a sub-step of performing the following sub-step (A1-2ex) is mentioned, but the sub-step (A1-2) is not limited to the sub-step (A1-2ex).

(120) <Sub-Step (A1-2ex)>

(121) An eluent d2 having the second strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 1 as the eluent supply port D2, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 4 as the weakly adsorptive fraction extraction port A.

(122) As an example of the sub-step (A2-2), a sub-step of performing the following sub-step (A2-2ex) is mentioned, but the sub-step (A2-2) is not limited to the sub-step (A2-2ex).

(123) <Sub-Step (A2-2ex)>

(124) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 3 as the eluent

supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(125) The eluent supply port D1 in this sub-step (A2-2ex) is provided on the same pipe as that for the eluent supply port D2 in the sub-step (A1-2ex). Furthermore, the eluent supply port D3 is provided on the same pipe as that for the feed solution supply port F in the sub-step (A1-2ex).

(126) As an example of the sub-step (A3-2), a sub-step of performing the following sub-step (A3-2ex) is mentioned, but the sub-step (A3-2) is not limited to the sub-step (A3-2ex).

(127) <Sub-Step (A3-2ex)>

(128) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2 in the sub-step (A2-2ex), an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of the four kinds of eluents from an eluent supply port D4 while using an upstream end of the section 4 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(129) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-2ex), (A2-2ex), and (A3-2ex) are sequentially performed in the step (A) is illustrated in FIG. 4. In FIG. 4, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(130) After the step (A) in which the sub-steps (A1-2ex), (A2-2ex), and (A3-2ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-2ex), (A2-2ex), and (A3-2ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 5. The unit packed column arranged in each section illustrated in FIG. 4 is shifted to the downstream side one by one in FIG. 5. In this case, a process in which the step (A) illustrated in FIG. 4 is started and then the step (B) is performed is designated as one set, this process is performed for four sets, and it returns to the embodiment illustrated in FIG. 4 again.

Embodiment 3

(131) In Embodiment 3, a circulation system having five or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(132) In this Embodiment 3, the following sub-steps (A1-3), (A2-3), and (A3-3) are sequentially performed as the step (A).

(133) <Sub-Step (A1-3)>

(134) An eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, a feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A, thereby most strengthening desorption strength of the eluent passing through the sections 1 and 2, setting desorption strength of the eluent passing through the section 3 equal to the desorption strength of the eluent passing through the sections 1 and 2 or weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the sections 1 and 2, and weakening desorption strength of the eluent passing

through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3.

<Sub-Step (A2-3)>

(135) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, the eluent d-III is supplied from the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

(136) The desorption strength of the eluent passing through the section 1 in the sub-step (A2-3) is preferably stronger than the desorption strength of the eluent passing through the section 1 in the sub-step (A1-3).

(137) The eluent supply port D-I in this sub-step (A2-3) is provided on the same pipe as that for the eluent supply port D-II in the sub-step (A1-3).

(138) <Sub-Step (A3-3)>

(139) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II in the sub-step (A2-3), an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 5 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2, 3, and 4 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 5 more than the desorption strength of the eluent passing through the sections 2, 3, and 4.

(140) As an example of the sub-step (A1-3), a sub-step of performing the following sub-step (A1-3ex) is mentioned, but the sub-step (A1-3) is not limited to the sub-step (A1-3ex).

(141) <Sub-Step (A1-3ex)>

(142) An eluent d2 having the second strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 1 as the eluent supply port D2, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(143) As an example of the sub-step (A2-3), a sub-step of performing the following sub-step (A2-3ex) is mentioned, but the sub-step (A2-3) is not limited to the sub-step (A2-3ex).

(144) <Sub-Step (A2-3ex)>

(145) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is

supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, the eluent d3 is supplied from the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(146) The eluent supply port D1 in this sub-step (A2-3ex) is provided on the same pipe as that for the eluent supply port D2 in the sub-step (A1-3ex).

(147) As an example of the sub-step (A3-3), a sub-step of performing the following sub-step (A3-3ex) is mentioned, but the sub-step (A3-3) is not limited to the sub-step (A3-3ex).

(148) <Sub-Step (A3-3ex)>

(149) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2 in the sub-step (A2-3ex), an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of the four kinds of eluents from an eluent supply port D4 while using an upstream end of the section 5 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(150) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-3ex), (A2-3ex), and (A3-3ex) are sequentially performed in the step (A) is illustrated in FIG. 6. In FIG. 6, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(151) After the step (A) in which the sub-steps (A1-3ex), (A2-3ex), and (A3-3ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-3ex), (A2-3ex), and (A3-3ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 7. The unit packed column arranged in each section illustrated in FIG. 6 is shifted to the downstream side one by one in FIG. 7. In this case, a process in which the step (A) illustrated in FIG. 6 is started and then the step (B) is performed is designated as one set, this process is performed for five sets, and it returns to the embodiment illustrated in FIG. 6 again.

Embodiment 4

(152) In Embodiment 4, a circulation system having seven or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, five kinds of eluents d-I to d-V each having different desorption strength are used.

(153) In this Embodiment 4, the following sub-steps (A1-4), (A2-4), and (A3-4) are sequentially performed as the step (A).

(154) <Sub-Step (A1-4)>

(155) An eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, a feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A while using a downstream end of the section 5 as the extraction port A, thereby most strengthening desorption strength of the eluent passing through the sections 1 and 2, setting desorption strength of the eluent passing through the section 3 to be equal to the desorption strength of the eluent passing through the sections 1 and 2 or weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the sections 1 and 2, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the

desorption strength of the eluent passing through the section 3.

<Sub-Step (A2-4)>

(156) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

(157) The desorption strength of the eluent passing through the section 1 in the sub-step (A2-4) is preferably stronger than the desorption strength of the eluent passing through the section 1 in the sub-step (A1-4).

(158) The eluent supply port D-I in this sub-step (A2-4) is provided on the same pipe as that for the eluent supply port D-II in the sub-step (A1-4).

(159) <Sub-Step (A3-4)>

(160) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d2 is supplied from the eluent supply port D2 in the sub-step (A2-4), an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d-V is supplied from an eluent supply port D-V while using an upstream end of the section 5 as the eluent supply port D-V, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2, 3, and 4 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 5 more than the desorption strength of the eluent passing through the sections 2, 3, and 4.

(161) As an example of the sub-step (A1-4), a sub-step of performing the following sub-step (A1-4ex) is mentioned, but the sub-step (A1-4) is not limited to the sub-step (A1-4ex).

(162) <Sub-Step (A1-4ex)>

(163) An eluent d2 having the second strongest desorption strength of five kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 1 as the eluent supply port D2, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d3 having the weakest desorption strength of the five kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(164) The desorption strength of the eluent passing through the sections 4 and 5 in the sub-step (A3-3) is also preferably equal to the desorption strength of the eluent passing through the section 5 in the sub-step (A3-4).

(165) As an example of the sub-step (A2-4), a sub-step of performing the following sub-step (A2-4ex) is mentioned, but the sub-step (A2-4) is not limited to the sub-step (A2-4ex).

(166) <Sub-Step (A2-4ex)>

(167) An eluent d1 having the strongest desorption strength of five kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply

port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the five kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, an eluent d4 having the fourth strongest desorption strength of the five kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 4 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(168) The eluent supply port D1 in this sub-step (A2-4ex) is provided on the same pipe as that for the eluent supply port D2 in the sub-step (A1-4ex).

(169) As an example of the sub-step (A3-4), a sub-step of performing the following sub-step (A3-4ex) is mentioned, but the sub-step (A3-4) is not limited to the sub-step (A3-4ex).

(170) <Sub-Step (A3-4ex)>

(171) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2 in the sub-step (A2-4ex), an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d5 having the third strongest desorption strength of the five kinds of eluents from an eluent supply port D5 while using an upstream end of the section 5 as the eluent supply port D5, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(172) A flow diagram in a case where the sub-steps (A1-4ex), (A2-4ex), and (A3-4ex) are sequentially performed in the step (A) is illustrated in FIG. 8. In FIG. 8, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column. Furthermore, an embodiment illustrated in FIG. 8 has seven unit packed columns and includes one unit packed column in the section 1, two unit packed columns in the section 2, two unit packed columns in the section 3, one unit packed column in the section 4, and one unit packed column in the section 5.

(173) After the step (A) in which the sub-steps (A1-4ex), (A2-4ex), and (A3-4ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-4ex), (A2-4ex), and (A3-4ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 9. The unit packed column arranged in each section illustrated in FIG. 8 is shifted to the downstream side by one unit packed column in FIG. 9. In this case, a process in which the step (A) illustrated in FIG. 8 is started and then the step (B) is performed is designated as one set, this process is performed at seven sets, and it returns to the embodiment illustrated in FIG. 8 again.

Embodiment 5

(174) In Embodiment 5, a circulation system having five or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(175) In this Embodiment 5, the following sub-steps (A1-5), (A2-5), and (A3-5) are sequentially performed as the step (A).

(176) <Sub-Step (A1-5)>

(177) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a

weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 3, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3.

<Sub-Step (A2-5)>

(178) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, the eluent d-III is supplied from the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

<Sub-Step (A3-5)>

(179) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 5 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2, 3, and 4 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 5 more than the desorption strength of the eluent passing through the sections 2, 3, and 4.

(180) The desorption strength of the eluent passing through the section 1 in the sub-step (A3-5) is preferably equal to the desorption strength of the eluent passing through the section 1 in the sub-step (A2-5).

(181) As an example of the sub-step (A1-5), a sub-step of performing the following sub-step (A1-5ex) is mentioned, but the sub-step (A1-5) is not limited to the sub-step (A1-5ex).

(182) <Sub-Step (A1-5ex)>

(183) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d3 having the weakest desorption strength of four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(184) As an example of the sub-step (A2-5), a sub-step of performing the following sub-step (A2-5ex) is mentioned, but the sub-step (A2-5) is not limited to the sub-step (A2-5ex).

(185) <Sub-Step (A2-5ex)>

(186) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent

supply port D2, the eluent d3 is supplied from the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(187) As an example of the sub-step (A3-5), a sub-step of performing the following sub-step (A3-5ex) is mentioned, but the sub-step (A3-5) is not limited to the sub-step (A3-5ex).

(188) <Sub-Step (A3-5ex)>

(189) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 5 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(190) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-5ex), (A2-5ex), and (A3-5ex) are sequentially performed in the step (A) is illustrated in FIG. 13. In FIG. 13, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(191) After the step (A) in which the sub-steps (A1-5ex), (A2-5ex), and (A3-5ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-5ex), (A2-5ex), and (A3-5ex) are sequentially performed. The flow diagram in this case is illustrated in FIG.

14. The unit packed column arranged in each section illustrated in FIG. 13 is shifted to the downstream side one by one in FIG. 14. In this case, a process in which the step (A) illustrated in FIG. 13 is started and then the step (B) is performed is designated as one set, this process is performed for five sets, and it returns to the embodiment illustrated in FIG. 13 again.

Embodiment 6

(192) In Embodiment 6, a circulation system having five or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(193) In this Embodiment 6, the following sub-steps (A1-6), (A2-6), and (A3-6) are sequentially performed as the step (A).

(194) <Sub-Step (A1-6)>

(195) An eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A, thereby most strengthening desorption strength of the eluent passing through the sections 1, 2, and 3, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 1, 2, and 3.

<Sub-Step (A2-6)>

(196) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly

adsorptive fraction extraction port C, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3.

(197) The desorption strength of the eluent passing through the section 1 in the sub-step (A2-6) is preferably stronger than the desorption strength of the eluent passing through the section 1 in the sub-step (A1-6).

(198) The eluent supply port D-I in this sub-step (A2-6) is provided on the same pipe as that for the eluent supply port D-II in the sub-step (A1-6).

(199) <Sub-Step (A3-6)>

(200) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, the eluent d-III is supplied from the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

(201) The desorption strength of the eluent passing through the section 1 in the sub-step (A3-6) is preferably equal to the desorption strength of the eluent passing through the section 1 in the sub-step (A2-6).

(202) As an example of the sub-step (A1-6), a sub-step of performing the following sub-step (A1-6ex) is mentioned, but the sub-step (A1-6) is not limited to the sub-step (A1-6ex).

(203) <Sub-Step (A1-6ex)>

(204) An eluent d2 having the second strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 1 as the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 4 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(205) As an example of the sub-step (A2-6), a sub-step of performing the following sub-step (A2-6ex) is mentioned, but the sub-step (A2-6) is not limited to the sub-step (A2-6ex).

(206) <Sub-Step (A2-6ex)>

(207) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is

extracted from the weakly adsorptive fraction extraction port A.

(208) As an example of the sub-step (A3-6), a sub-step of performing the following sub-step (A3-6ex) is mentioned, but the sub-step (A3-6) is not limited to the sub-step (A3-6ex).

(209) <Sub-Step (A3-6ex)>

(210) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, the eluent d3 is supplied from the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(211) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-6ex), (A2-6ex), and (A3-6ex) are sequentially performed in the step (A) is illustrated in FIG. 15. In FIG. 15, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(212) After the step (A) in which the sub-steps (A1-6ex), (A2-6ex), and (A3-6ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-6ex), (A2-6ex), and (A3-6ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 16. The unit packed column arranged in each section illustrated in FIG. 15 is shifted to the downstream side one by one in FIG. 16. In this case, a process in which the step (A) illustrated in FIG. 15 is started and then the step (B) is performed is designated as one set, this process is performed for five sets, and it returns to the embodiment illustrated in FIG. 15 again.

Embodiment 7

(213) In Embodiment 7, a circulation system having five or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(214) In this Embodiment 7, the following sub-steps (A1-7), (A2-7), and (A3-7) are sequentially performed as the step (A).

(215) <Sub-Step (A1-7)>

(216) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, a feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A while using a downstream end of the section 5 as the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3.

<Sub-Step (A2-7)>

(217) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, the eluent d-III is supplied from the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the

section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

<Sub-Step (A3-7)>

(218) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 5 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2, 3, and 4 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 5 more than the desorption strength of the eluent passing through the sections 2, 3, and 4.

(219) As an example of the sub-step (A1-7), a sub-step of performing the following sub-step (A1-7ex) is mentioned, but the sub-step (A1-7) is not limited to the sub-step (A1-7ex).

(220) <Sub-Step (A1-7ex)>

(221) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, a feed solution is supplied from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(222) As an example of the sub-step (A2-7), a sub-step of performing the following sub-step (A2-7ex) is mentioned, but the sub-step (A2-7) is not limited to the sub-step (A2-7ex).

(223) <Sub-Step (A2-7ex)>

(224) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d3 is supplied from the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(225) As an example of the sub-step (A3-7), a sub-step of performing the following sub-step (A3-7ex) is mentioned, but the sub-step (A3-7) is not limited to the sub-step (A3-7ex).

(226) <Sub-Step (A3-7ex)>

(227) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 4 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 5 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(228) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-7ex), (A2-7ex), and (A3-7ex) are sequentially performed in the step (A) is illustrated in FIG. 17. In FIG. 17, a square enclosure indicates one unit

packed column, and the number in the enclosure indicates the number of the unit packed column. (229) After the step (A) in which the sub-steps (A1-7ex), (A2-7ex), and (A3-7ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-7ex), (A2-7ex), and (A3-7ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 18. The unit packed column arranged in each section illustrated in FIG. 17 is shifted to the downstream side one by one in FIG. 18. In this case, a process in which the step (A) illustrated in FIG. 17 is started and then the step (B) is performed is designated as one set, this process is performed for five sets, and it returns to the embodiment illustrated in FIG. 17 again.

Embodiment 8

(230) In Embodiment 8, a circulation system having three or more unit packed columns is used. Here, it is assumed that this circulation system is divided into three sections 1 to 3 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(231) In this Embodiment 8, the following sub-steps (A1-8), (A2-8), (A3-8), and (A4-8) are sequentially performed as the step (A).

(232) <Sub-Step (A1-8)>

(233) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 3 as the weakly adsorptive fraction extraction port A.

(234) <Sub-Step (A2-8)>

(235) An eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 2 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1.

<Sub-Step (A3-8)>

(236) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 3 more than the desorption strength of the eluent passing through the section 2.

<Sub-Step (A4-8)>

(237) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an

upstream end of the section 3 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

(238) The desorption strength of the eluent passing through the section 1 in the sub-step (A4-8) is preferably equal to the desorption strength of the eluent passing through the section 1 in the sub-step (A3-8).

(239) As an example of the sub-step (A2-8), a sub-step of performing the following sub-step (A2-8ex) is mentioned, but the sub-step (A2-8) is not limited to the sub-step (A2-8ex).

(240) <Sub-Step (A2-8ex)>

(241) An eluent d2 having the second strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 1 as the eluent supply port D2, an eluent d3 having the weakest desorption strength of four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 2 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(242) As an example of the sub-step (A3-8), a sub-step of performing the following sub-step (A3-8ex) is mentioned, but the sub-step (A3-8) is not limited to the sub-step (A3-8ex).

(243) <Sub-Step (A3-8ex)>

(244) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 3 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(245) As an example of the sub-step (A4-8), a sub-step of performing the following sub-step (A4-8ex) is mentioned, but the sub-step (A4-8) is not limited to the sub-step (A4-8ex).

(246) <Sub-Step (A4-8ex)>

(247) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents from an eluent supply port D4 while using an upstream end of the section 3 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(248) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-8), (A2-8ex), (A3-8ex), and (A4-8ex) are sequentially performed in the step (A) is illustrated in FIG. 19. In FIG. 19, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(249) After the step (A) in which the sub-steps (A1-8), (A2-8ex), (A3-8ex), and (A4-8ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while

maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-8), (A2-8ex), (A3-8ex), and (A4-8ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 20. The unit packed column arranged in each section illustrated in FIG. 19 is shifted to the downstream side one by one in FIG. 20. In this case, a process in which the step (A) illustrated in FIG. 19 is started and then the step (B) is performed is designated as one set, this process is performed for three sets, and it returns to the embodiment illustrated in FIG. 19 again.

Embodiment 9

(250) In Embodiment 9, a circulation system having three or more unit packed columns is used. Here, it is assumed that this circulation system is divided into three sections 1 to 3 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(251) In this Embodiment 9, the following sub-steps (A1-9), (A2-9), (A3-9), and (A4-9) are sequentially performed as the step (A).

(252) <Sub-Step (A1-9)>

(253) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 3 as the weakly adsorptive fraction extraction port A.

(254) <Sub-Step (A2-9)>

(255) An eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 2 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1.

<Sub-Step (A3-9)>

(256) An eluent d-II is supplied from an eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the sections 1 and 2, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the sections 1 and 2.

<Sub-Step (A4-9)>

(257) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

(258) As an example of the sub-step (A2-9), a sub-step of performing the following sub-step (A2-

9ex) is mentioned, but the sub-step (A2-9) is not limited to the sub-step (A2-9ex).

(259) <Sub-Step (A2-9ex)>

(260) An eluent d2 having the second strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 1 as the eluent supply port D2, an eluent d3 having the weakest desorption strength of four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 2 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(261) As an example of the sub-step (A3-9), a sub-step of performing the following sub-step (A3-9ex) is mentioned, but the sub-step (A3-9) is not limited to the sub-step (A3-9ex).

(262) <Sub-Step (A3-9ex)>

(263) The eluent d2 is supplied from the eluent supply port D2, an eluent d3 having the weakest desorption strength of four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 3 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(264) As an example of the sub-step (A4-9), a sub-step of performing the following sub-step (A4-9ex) is mentioned, but the sub-step (A4-9) is not limited to the sub-step (A4-9ex).

(265) <Sub-Step (A4-9ex)>

(266) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 3 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(267) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-9), (A2-9ex), (A3-9ex), and (A4-9ex) are sequentially performed in the step (A) is illustrated in FIG. 21. In FIG. 21, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(268) After the step (A) in which the sub-steps (A1-9), (A2-9ex), (A3-9ex), and (A4-9ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-9), (A2-9ex), (A3-9ex), and (A4-9ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 22. The unit packed column arranged in each section illustrated in FIG. 21 is shifted to the downstream side one by one in FIG. 22. In this case, a process in which the step (A) illustrated in FIG. 21 is started and then the step (B) is performed is designated as one set, this process is performed for three sets, and it returns to the embodiment illustrated in FIG. 21 again.

Embodiment 10

(269) In Embodiment 10, a circulation system having three or more unit packed columns is used. Here, it is assumed that this circulation system is divided into three sections 1 to 3 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(270) In this Embodiment 10, the following sub-steps (A1-10), (A2-10), (A3-10), and (A4-10) are sequentially performed as the step (A).

(271) <Sub-Step (A1-10)>

(272) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 3 as the weakly adsorptive fraction extraction port A.

(273) <Sub-Step (A2-10)>

(274) An eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 2 as the eluent supply port D-IV and a weakly adsorptive fraction is extracted from the extraction port A. At this time, the relationship between the desorption strength of the stock solution and the desorption strength of the eluent d-IV in the sub-step (A1-10) is set so that the stock solution \leq d-IV.

(275) <Sub-Step (A3-10)>

(276) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 3 more than the desorption strength of the eluent passing through the section 2.

<Sub-Step (A4-10)>

(277) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

(278) The desorption strength of the eluent passing through the section 1 in the sub-step (A4-10) is preferably equal to the desorption strength of the eluent passing through the section 1 in the sub-step (A3-10).

(279) As an example of the sub-step (A2-10), a sub-step of performing the following sub-step (A2-10ex) is mentioned, but the sub-step (A2-10) is not limited to the sub-step (A2-10ex).

(280) <Sub-Step (A2-10ex)>

(281) An eluent d4 having the third strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 2 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(282) As an example of the sub-step (A3-10), a sub-step of performing the following sub-step (A3-10ex) is mentioned, but the sub-step (A3-10) is not limited to the sub-step (A3-10ex).

(283) <Sub-Step (A3-10ex)>

(284) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 3 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(285) As an example of the sub-step (A4-10), a sub-step of performing the following sub-step (A4-10ex) is mentioned, but the sub-step (A4-10) is not limited to the sub-step (A4-10ex).

(286) <Sub-Step (A4-10ex)>

(287) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents from an eluent supply port D4 while using an upstream end of the section 3 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(288) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-10), (A2-10ex), (A3-10ex), and (A4-10ex) are sequentially performed in the step (A) is illustrated in FIG. 23. In FIG. 23, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(289) After the step (A) in which the sub-steps (A1-10), (A2-10ex), (A3-10ex), and (A4-10ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-10), (A2-10ex), (A3-10ex), and (A4-10ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 24. The unit packed column arranged in each section illustrated in FIG. 23 is shifted to the downstream side one by one in FIG. 24. In this case, a process in which the step (A) illustrated in FIG. 23 is started and then the step (B) is performed is designated as one set, this process is performed for three sets, and it returns to the embodiment illustrated in FIG. 23 again.

Embodiment 11

(290) In Embodiment 11, a circulation system having five or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(291) In this Embodiment 8, the following sub-steps (A1-11), (A2-11), and (A3-11) are sequentially performed as the step (A).

(292) <Sub-Step (A1-11)>

(293) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while

using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 3, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3.

<Sub-Step (A2-11)>

(294) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, the eluent d-III is supplied from the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

<Sub-Step (A3-11)>

(295) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

(296) The desorption strength of the eluent passing through the section 1 in the sub-step (A3-11) is preferably equal to the desorption strength of the eluent passing through the section 1 in the sub-step (A2-11).

(297) As an example of the sub-step (A1-11), a sub-step of performing the following sub-step (A1-11ex) is mentioned, but the sub-step (A1-11) is not limited to the sub-step (A1-11ex).

(298) <Sub-Step (A1-11ex)>

(299) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, an eluent d3 having the weakest desorption strength of four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(300) As an example of the sub-step (A2-11), a sub-step of performing the following sub-step (A2-11ex) is mentioned, but the sub-step (A2-11) is not limited to the sub-step (A2-11ex).

(301) <Sub-Step (A2-11ex)>

(302) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, the eluent d3 is supplied from the eluent supply port D3, and a weakly adsorptive

fraction is extracted from the weakly adsorptive fraction extraction port A.

(303) As an example of the sub-step (A3-11), a sub-step of performing the following sub-step (A3-11ex) is mentioned, but the sub-step (A3-11) is not limited to the sub-step (A3-11ex).

(304) <Sub-Step (A3-11ex)>

(305) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 4 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(306) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-11ex), (A2-11ex), and (A3-11ex) are sequentially performed in the step (A) is illustrated in FIG. 25. In FIG. 25, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(307) After the step (A) in which the sub-steps (A1-11ex), (A2-11ex), and (A3-11ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-11ex), (A2-11ex), and (A3-11ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 26. The unit packed column arranged in each section illustrated in FIG. 25 is shifted to the downstream side one by one in FIG. 26. In this case, a process in which the step (A) illustrated in FIG. 25 is started and then the step (B) is performed is designated as one set, this process is performed for five sets, and it returns to the embodiment illustrated in FIG. 25 again.

Embodiment 12

(308) In Embodiment 12, a circulation system having five or more unit packed columns is used. Here, it is assumed that this circulation system is divided into five sections 1 to 5 that are annularly continuous from the upstream side to the downstream side such that each section has at least one unit packed column. Further, as the eluent, four kinds of eluents d-I to d-IV each having different desorption strength are used.

(309) In this Embodiment 12, the following sub-steps (A1-12), (A2-12), (A3-12), and (A4-12) are sequentially performed as the step (A).

(310) <Sub-Step (A1-12)>

(311) A feed solution is supplied from a feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F and a weakly adsorptive fraction is extracted from a weakly adsorptive fraction extraction port A while using a downstream end of the section 5 as the weakly adsorptive fraction extraction port A.

(312) <Sub-Step (A2-12)>

(313) An eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV and a weakly adsorptive fraction is extracted from the extraction port A. At this time, the relationship between the desorption strength of the stock solution and the desorption strength of the eluent d-IV in the sub-step (A1-9) is set so that the stock solution \leq d-IV.

(314) <Sub-Step (A3-12)>

(315) An eluent d-I is supplied from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, a strongly adsorptive fraction is extracted from a strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d-II is supplied from an eluent supply port D-II

while using an upstream end of the section 2 as the eluent supply port D-II, an eluent d-III is supplied from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

<Sub-Step (A4-12)>

(316) The eluent d-I is supplied from the eluent supply port D-I, a strongly adsorptive fraction is extracted from the extraction port C, the eluent d-II is supplied from the eluent supply port D-II, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the intermediately adsorptive fraction extraction port B, an eluent d-IV is supplied from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and a weakly adsorptive fraction is extracted from the extraction port A, thereby most strengthening desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

(317) The desorption strength of the eluent passing through the section 1 in the sub-step (A4-12) is preferably equal to the desorption strength of the eluent passing through the section 1 in the sub-step (A3-12).

(318) As an example of the sub-step (A2-12), a sub-step of performing the following sub-step (A2-12ex) is mentioned, but the sub-step (A2-12) is not limited to the sub-step (A2-12ex).

(319) <Sub-Step (A2-12ex)>

(320) An eluent d4 having the third strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 3 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(321) As an example of the sub-step (A3-12), a sub-step of performing the following sub-step (A3-12ex) is mentioned, but the sub-step (A3-12) is not limited to the sub-step (A3-12ex).

(322) <Sub-Step (A3-12ex)>

(323) An eluent d1 having the strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D1 while using an upstream end of the section 1 as the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, an eluent d2 having the second strongest desorption strength of the four kinds of eluents is supplied from an eluent supply port D2 while using an upstream end of the section 2 as the eluent supply port D2, an eluent d3 having the weakest desorption strength of the four kinds of eluents is supplied from an eluent supply port D3 while using an upstream end of the section 4 as the eluent supply port D3, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(324) As an example of the sub-step (A4-12), a sub-step of performing the following sub-step (A4-12ex) is mentioned, but the sub-step (A4-12) is not limited to the sub-step (A4-12ex).

(325) <Sub-Step (A4-12ex)>

(326) The eluent d1 is supplied from the eluent supply port D1, a strongly adsorptive fraction is extracted from the strongly adsorptive fraction extraction port C, the eluent d2 is supplied from the eluent supply port D2, an intermediately adsorptive fraction is extracted from an intermediately adsorptive fraction extraction port B while using a downstream end of the section 3 as the

intermediately adsorptive fraction extraction port B, an eluent d4 having the third strongest desorption strength of four kinds of eluents is supplied from an eluent supply port D4 while using an upstream end of the section 4 as the eluent supply port D4, and a weakly adsorptive fraction is extracted from the weakly adsorptive fraction extraction port A.

(327) A case where each section has one unit packed column is used as an example, and a flow diagram in a case where the sub-steps (A1-12), (A2-12ex), (A3-12ex), and (A4-12ex) are sequentially performed in the step (A) is illustrated in FIG. 27. In FIG. 27, a square enclosure indicates one unit packed column, and the number in the enclosure indicates the number of the unit packed column.

(328) After the step (A) in which the sub-steps (A1-12), (A2-12ex), (A3-12ex), and (A4-12ex) are sequentially performed, the feed solution supply port F, the eluent supply port D, the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C are shifted to the downstream side, while maintaining a relative positional relationship therebetween, by the step (B), and then the sub-steps (A1-12), (A2-12ex), (A3-12ex), and (A4-12ex) are sequentially performed. The flow diagram in this case is illustrated in FIG. 28. The unit packed column arranged in each section illustrated in FIG. 27 is shifted to the downstream side one by one in FIG. 28. In this case, a process in which the step (A) illustrated in FIG. 27 is started and then the step (B) is performed is designated as one set, this process is performed for five sets, and it returns to the embodiment illustrated in FIG. 27 again.

(329) In the method of the present invention, supply of a target liquid to a target place or extraction of a target liquid from a target extraction place can be performed by appropriately adjusting the operation of a pump at each place and opening/closing of a valve at each place which are provided in a circulation system. That is, methods of supplying a target fluid and extracting a target fraction in a circulation system are publicly known. Furthermore, the supply flow rate and the extraction flow rate of each liquid can also be appropriately set depending on purposes such as processing efficiency.

(330) In the method of the present invention, a purification target component may be any one of a strongly adsorptive component, an intermediately adsorptive component, and a weakly adsorptive component, and in particular, the method of the present invention is a suitable method for purifying an intermediately adsorptive component. The method of the present invention can be suitably used for purification of protein. Since an intermediately adsorptive component can be obtained at a high purity by the method of the present invention, the method of the present invention is a suitable method for obtaining a target protein from a feed solution containing a target protein as well as a digest or aggregate thereof.

(331) The protein is not particularly limited, and for example, an antibody can be used as a purification target component. In the present invention, the “antibody” may be a naturally occurring antibody, a chimeric antibody, and an antibody fragmented by an enzyme or the like (for example, F(ab').sub.2 fragment, Fab' fragment, or Fab fragment). Also included are single chain antibodies, dimers (diabodies) or trimers (triabodies) thereof, or minibodies. Alternatively, the antibody may be a single domain antibody. Incidentally, these are merely examples, all of proteins having a specific binding ability with respect to antigens and derivatives thereof are included in the concept of the antibody in the present invention.

(332) An antibody highly purified by the method of the present invention can be applied as an antibody drug. That is, an antibody contained in a feed solution is fractionated by applying the method of the present invention, so that a method of producing an antibody drug can be provided. More specifically, according to the method of the present invention, an antibody drug can be obtained by using a culture solution for antibody-producing cells and/or an extract from antibody-producing cells as a feed solution and fractionating an antibody contained in the feed solution. In the present invention, the meaning of the term “culture solution for antibody-producing cells” or “extract from antibody-producing cells” includes a state where the culture solution for antibody-

producing cells or the extract from antibody-producing cells is subjected to various processing such as centrifugation and/or chromatography to be fractionated, purified, etc. to some extent.

(333) In the method of the present invention, an adsorbent to be packed in the unit packed column is appropriately selected according to a purification target component, and various adsorbents can be adopted. For example, a strongly acidic cation-exchange resin, a weakly acidic cation-exchange resin, a strongly basic anion-exchange resin, a weakly basic anion-exchange resin, a synthetic adsorbent, zeolite, silica gel, functional group-modified silica gel (preferably octadecylsilyl-modified silica gel), other materials for gel filtration chromatography, or an affinity adsorbent can be used as the adsorbent.

(334) In a case where a purification target component is protein, the adsorbent is preferably an ion-exchange resin. In particular, a cation-exchange resin can be suitably used.

(335) The simulated moving-bed type chromatographic separation system of the present invention is a system for implementing the method of the present invention. That is, the simulated moving-bed type chromatographic separation system of the present invention is a system having the configuration of the circulation system described above, in which the circulation system can sequentially repeat the operation of the step (A) and the operation of the step (B) as described above.

EXAMPLES

(336) Hereinafter, the present invention will be described in more detail on the basis of Examples; however, the present invention is not limited to the following Examples.

(337) [Preparation of Feed Solution]

(338) Cells producing immune globulin G2 (IgG2) of human being were cultured, the supernatant of the culture solution was desalted by dialysis, and the salt concentration was adjusted by addition of NaCl to prepare a feed solution. The contents of the antibody, and fragments and aggregate thereof contained in this supernatant are as described below. In the following table, the fragment 1 was set as proteins contained in a fraction having a molecular weight of less than 25,000 and having a peak around a molecular weight of 5,000, and the fragment 2 was set as proteins contained in a fraction having a molecular weight of 25,000 or more and less than 50,000. Furthermore, the antibody was set as proteins contained in a fraction having a peak near a molecular weight of 150,000 and having a molecular weight of 50,000 or more and less than 300,000. Furthermore, the aggregate was set as proteins contained in a fraction having a molecular weight of 300,000 or more. The component compositions described below were determined by high-performance liquid chromatography (HPLC) using an analytical column (Tosoh Corporation TSKgel G3000SWXL).

(339) [Table 1]

(340) TABLE-US-00001 TABLE 1 Component in supernatant of culture solution Concentration (g/L) Fragment 1 0.02 Fragment 2 0.326 Antibody 1.564 Aggregate 0.090

[Adsorbent Used in Unit Packed Column (Column)]

(341) A cation exchange resin (trade name: Fractogel (registered trademark) EMD SO.sub.3.sup.- (M), manufactured by Merck KGaA, Darmstadt, Germany) was used as the adsorbent.

(342) [Eluent]

(343) Phosphate buffer solutions having various NaCl concentrations were prepared by using the following A liquid and B liquid and were used as the eluent.

(344) <A Liquid>

(345) 20 mM Phosphate buffer (pH 6.0)

(346) <B Liquid>

(347) 20 mM Phosphate buffer containing NaCl at a concentration of 0.3 M (17.53 g/L) (pH 6.0)

[Comparative Example 1] Single Column Step Gradient

(348) <Column>

(349) One column having a size of an inner diameter of 10 mm×a length of 100 mm

(350) <Feed Solution>

(351) The NaCl concentration in the feed solution was set to 2.05 g/L.

(352) <Eluent>

(353) The following eluents were used.

(354) [Table 2]

(355) TABLE-US-00002 TABLE 2 Eluent type NaCl concentration (g/L) of eluent D1 2.39 D2 2.66 D3 17.53

<Operation Conditions>

(356) The following steps 1 to 6 were sequentially performed. The flow diagram for the steps 1 to 6 is shown in FIG. 10.

(357) The following operation conditions were set such that the recovery percentages for the fragment 1 and the fragment 2 into the weakly adsorptive fraction became 98% or more, the recovery percentage for the antibody into the intermediately adsorptive fraction became 98% or more, and the recovery percentage for the aggregate into the strongly adsorptive fraction became 98% or more. This is also the same in each of Comparative Examples or Examples described below.

(358) [Table 3]

(359) TABLE-US-00003 TABLE 3 Step Time (min.) Flow velocity (mL/min.) 1 5.03 9.11 2 8.50 9.11 3 0.71 9.11 4 39.46 9.11 5 0.66 9.11 6 3.60 9.11

<Results>

—Recovery Percentage—

(360) The recovery percentages for the fragment 1 and the fragment 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table. This recovery percentage is calculated by $100 \times [\text{Mass in the fraction}] / [\text{Mass in the feed solution}]$.

(361) [Table 4]

(362) TABLE-US-00004 TABLE 4 Recovered Recovery Fraction component percentage (%)
Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.2 Intermediately adsorptive fraction
Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(363) The treated amount of the feed solution (unit: “L (liter)-feed solution”) per volume of the adsorbent (unit: “L (liter)-R”; R is an abbreviation for Resin) and per time (unit: “h (hour)”) was designated as the separation treatment efficiency. Incidentally, in the multi-column system using a plurality of columns described below, the volume of the adsorbent is the total amount of adsorbents contained in all of the columns.

(364) The separation treatment efficiency in Comparative Example 1 was 6.04 (L-feed solution)/(L-R).Math.h.

[Comparative Example 2] Single Column Step Gradient

(365) <Column>

(366) One column having a size of an inner diameter of 10 mm×a length of 400 mm

(367) <Feed Solution>

(368) The NaCl concentration in the feed solution was set to 2.05 g/L.

(369) <Eluent>

(370) The following eluents were used.

(371) [Table 5]

(372) TABLE-US-00005 TABLE 5 Eluent type NaCl concentration (g/L) of eluent D1 2.35 D2 2.62 D3 17.53

<Operation Conditions>

(373) The following steps 1 to 6 were sequentially performed. The flow diagram of the steps 1 to 6

is as illustrated in FIG. 10.

(374) [Table 6]

(375) TABLE-US-00006 TABLE 6 Step Time (min.) Flow velocity (mL/min.) 1 5.99 43.3 2 6.35 43.3 3 0.63 43.3 4 22.48 43.3 5 0.58 43.3 6 3.55 43.3

<Results>

—Recovery Percentage—

(376) The recovery percentages for the fragment 1 and the fragment 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(377) [Table 7]

(378) TABLE-US-00007 TABLE 7 Recovered Recovery Fraction component percentage (%)
Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction
Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(379) The separation treatment efficiency in Comparative Example 2 was 12.51 (L-feed solution)/(L-R).Math.h.

[Comparative Example 3] Multi-Column Gradient Simulated Moving-Bed Type

(380) <Column>

(381) Four columns having a size of an inner diameter of 10 mm×a length of 100 mm

(382) <Feed Solution>

(383) The NaCl concentration in the feed solution was set to 2.23 g/L.

(384) <Eluent>

(385) The following eluents were used.

(386) [Table 8]

(387) TABLE-US-00008 TABLE 8 Eluent type NaCl concentration (g/L) of eluent D1 17.53 D2 2.28 D3 2.23

<Operation Conditions>

(388) A flow diagram of operation in Comparative Example 3 is illustrated in FIG. 11. While the first to fourth steps shown in FIG. 11 are set as 1 cycle, 10 cycles were performed. A step of shifting the feed solution supply port F, the eluent supply port D (D1 to D3), the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, and the strongly adsorptive fraction extraction port C to the downstream side by one column while maintaining the relative positional relationships thereof is performed between the respective steps.

(389) Note that although the first to fourth steps illustrated in FIG. 11 correspond to step (A) of the present invention, unlike step (A), the first to fourth steps do not include a plurality of sub-steps (In other words, one sub-step constitutes one step). All of “D1”, “D2”, and “D3” in FIG. 11 are eluent supply ports, and the eluents D1, D2, and D3 are supplied thereto, respectively. “C” in FIG. 11 indicates a strongly adsorptive fraction extraction port and a strongly adsorptive fraction is extracted therefrom. Similarly, “B” indicates an intermediately adsorptive fraction extraction port and an intermediately adsorptive fraction is extracted therefrom, and “A” indicates a weakly adsorptive fraction extraction port and a weakly adsorptive fraction is extracted therefrom.

(390) The supply flow velocities of the eluents (D1 to D3) and the feed solution (F) in each step illustrated in FIG. 11 are set as described below. Incidentally, although the flow velocity of the liquid to be extracted is not described in the following table, the flow velocity of the strongly adsorptive fraction extracted from the strongly adsorptive fraction extraction port C is the same as the flow velocity of the eluent D1 supplied. Furthermore, the flow velocity of the intermediately adsorptive fraction extracted from the intermediately adsorptive fraction extraction port B is the same as the flow velocity of the eluent D2 supplied. Furthermore, the flow velocity of the weakly adsorptive fraction extracted from the weakly adsorptive fraction extraction port A is the total of

the flow velocity of the eluent D3 supplied and the flow velocity of the feed solution supplied from the feed solution supply port F. That is, the supply flow velocity and the extraction flow velocity are the same at all times, and the same applies to Comparative Examples and Examples described below.

(391) [Table 9]

(392) TABLE-US-00009 TABLE 9 Flow velocity (mL/min.) Time (min.) of one step D1 D2 D3 F
29.9 2.14 18.7 1.79 3.73

<Results>

—Recovery Percentage—

(393) The recovery percentages for the fragment 1 and the fragment 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(394) [Table 10]

(395) TABLE-US-00010 TABLE 10 Recovered Recovery Fraction component percentage (%)
Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 Over 99 Intermediately adsorptive
fraction Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(396) The separation treatment efficiency in Comparative Example 3 was 7.11 (L-feed solution)/(L-R).Math.h.

[Comparative Example 4] Multi-Column Gradient Simulated Moving-Bed Type

(397) <Column>

(398) Four columns having a size of an inner diameter of 10 mm×a length of 100 mm

(399) <Feed Solution>

(400) The NaCl concentration in the feed solution was set to 2.24 g/L.

(401) <Eluent>

(402) The following eluents were used.

(403) [Table 11]

(404) TABLE-US-00011 TABLE 11 Eluent type NaCl concentration (g/L) of eluent D1 17.53 D2
2.26 D3 2.24

<Operation Conditions>

(405) A flow diagram of operation in Comparative Example 4 is illustrated in FIG. 12. While the first to fourth steps shown in FIG. 12 are set as 1 cycle, 10 cycles were performed. Note that each step shown in FIG. 12 includes two sub-steps: a first sub-step and a second sub-step, and in the second sub-step, the fluid in the circulation system is circulated without performing any of supply or extraction of the liquid.

(406) The supply flow velocities of the eluents (D1 to D3) and the feed solution (F) in each step illustrated in FIG. 12 are set as described below.

(407) [Table 12]

(408) TABLE-US-00012 TABLE 12 Time (min.) Flow velocity (mL/min.) of sub-step D1 D2 D3 F
First sub-step 32.7 1.90 17.4 1.33 3.82 Second sub-step 0.48 Circulation 0.94

<Results>

—Recovery Percentage—

(409) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(410) [Table 13]

(411) TABLE-US-00013 TABLE 13 Recovered Recovery Fraction component percentage (%)
Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 Over 99 Intermediately adsorptive
fraction Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(412) The separation treatment efficiency in Comparative Example 4 was 7.19 (L-feed solution)/(L-R).Math.h.

[Example 1] Multi-Column Gradient Simulated Moving-Bed Type

(413) <Column>

(414) Four columns having a size of an inner diameter of 10 mm×a length of 100 mm

(415) <Feed Solution>

(416) The NaCl concentration in the feed solution was set to 1.93 g/L.

(417) <Eluent>

(418) The following eluents were used.

(419) [Table 14]

(420) TABLE-US-00014 TABLE 14 Eluent type NaCl concentration (g/L) of eluent D1 17.53 D2 3.59 D3 1.93 D4 2.21

<Operation Conditions>

(421) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 2. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 4 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(422) [Table 15]

(423) TABLE-US-00015 TABLE 15 Time (min.) of sub-step Flow velocity (mL/min.) Sub-step 4.93 D1 D2 F (A1-1) 10.76 4.41 21.77 Sub-step 1.73 D1 D2 D3 (A2-1) 10.76 4.41 21.77 Sub-step 3.75 D1 D2 D4 (A3-1) 13.87 5.62 15.21

<Results>

—Recovery Percentage—

(424) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(425) [Table 16]

(426) TABLE-US-00016 TABLE 16 Recovered Recovery Fraction component percentage (%) Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(427) The separation treatment efficiency in Example 1 was 19.696 (L-feed solution)/(L-R).Math.h.

[Example 2] Multi-Column Gradient Simulated Moving-Bed Type

(428) <Column>

(429) Four columns having a size of an inner diameter of 10 mm× a length of 100 mm

(430) <Feed Solution>

(431) The NaCl concentration in the feed solution was set to 2.02 g/L.

(432) <Eluent>

(433) The following eluents were used.

(434) [Table 17]

(435) TABLE-US-00017 TABLE 17 Eluent type NaCl concentration (g/L) of eluent D1 17.53 D2 3.57 D3 2.02 D4 2.21

<Operation Conditions>

(436) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 4. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 4 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(437) [Table 18]

(438) TABLE-US-00018 TABLE 18 Time (min.) of sub-step Flow velocity (mL/min.) Sub-step

6.82 D2 F (A1-2) 2.39 17.65 Sub-step 1.67 D1 D2 D3 (A2-2) 3.25 2.39 17.65 Sub-step 3.86 D1 D2 D4 (A3-2) 7.80 5.38 7.37

<Results>

—Recovery Percentage—

(439) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(440) [Table 19]

(441) TABLE-US-00019 TABLE 19 Recovery Recovered percentage Fraction component (%)

Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction

Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(442) The separation treatment efficiency in Example 2 was 18.610 (L-feed solution)/(L-R).Math.h.

[Example 3] Multi-Column Gradient Simulated Moving-Bed Type

(443) <Column>

(444) Five columns having a size of an inner diameter of 10 mm× a length of 805 mm

(445) <Feed Solution>

(446) The NaCl concentration in the feed solution was set to 2.46 g/L.

(447) <Eluent>

(448) The following eluents were used.

(449) [Table 20]

(450) TABLE-US-00020 TABLE 20 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2

2.46 D3 0.00 D4 1.98

<Operation Conditions>

(451) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 6. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 5 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(452) [Table 21]

(453) TABLE-US-00021 TABLE 21 Time (min.) of one step Flow velocity (mL/min.) Sub-step

10.39 D2 D3 F (A1-3) 0.003 4.56 18.54 Sub-step 3.66 D1 D2 D3 (A2-3) 2.90 8.95 2.20 Sub-step

8.25 D1 D2 D4 (A3-3) 2.49 21.42 2.03

<Results>

—Recovery Percentage—

(454) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(455) [Table 22]

(456) TABLE-US-00022 TABLE 22 Recovery Recovered percentage Fraction component (%)

Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction

Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(457) The separation treatment efficiency in Example 3 was 16.499 (L-feed solution)/(L-R).Math.h.

[Example 4] Multi-Column Gradient Simulated Moving-Bed Type

(458) <Column>

(459) Seven columns having a size of an inner diameter of 10 mm×a length of 100 mm

(460) <Feed Solution>

(461) The NaCl concentration in the feed solution was set to 2.57 g/L.

(462) <Eluent>

(463) The following eluents were used.

(464) [Table 23]

(465) TABLE-US-00023 TABLE 23 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2 2.57 D3 0.00 D4 0.37 D5 1.80

<Operation Conditions>

(466) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 8. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 7 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D5) and the feed solution (F) supplied in each step (A) were set as described below.

(467) [Table 24]

(468) TABLE-US-00024 TABLE 24 Time (min.) of one step Flow velocity (mL/min.) Sub-step 8.18 D2 D3 F (A1-4) 0.004 6.86 16.07 Sub-step 3.84 D1 D2 D4 (A2-4) 2.94 10.68 5.73 Sub-step 4.47 D1 D2 D5 (A3-4) 3.43 19.02 2.18

<Results>

—Recovery Percentage—

(469) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(470) [Table 25]

(471) TABLE-US-00025 TABLE 25 Recovery Recovered percentage Fraction component (%)
Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction
Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(472) The separation treatment efficiency in Example 4 was 15.225 (L-feed solution)/(L-R).Math.h.

(473) As described above, it is found that, in the simulated moving-bed type chromatographic separation, a weakly adsorptive component, an intermediately adsorptive component, and a strongly adsorptive component can be sufficiently highly purified and fractionated with a smaller amount of the adsorbent used by using two or more kinds of eluents and setting the positional relationship between the weakly adsorptive fraction extraction port A, the intermediately adsorptive fraction extraction port B, the strongly adsorptive fraction extraction port C, and the feed solution supply port F in the circulation system to a specified relationship defined in the present invention. Based on the present examples, it is shown that a target antibody is obtainable at a high purity and with high efficiency in an intermediately adsorptive fraction.

[Example 5] Multi-Column Gradient Simulated Moving-Bed Type

(474) <Column>

(475) Five columns having a size of an inner diameter of 10 mm×a length of 80 mm

(476) <Feed Solution>

(477) The NaCl concentration in the feed solution was set to 2.46 g/L.

(478) <Eluent>

(479) The following eluents were used.

(480) [Table 26]

(481) TABLE-US-00026 TABLE 26 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2 2.46 D3 0.00 D4 1.98

(482) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 13. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 5 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(483) [Table 27]

(484) TABLE-US-00027 TABLE 27 Time (min.) of one step Flow velocity (mL/min.) Sub-step 10.39 D3 F (A1-5) 4.56 18.54 Sub-step 3.66 D1 D2 D3 D1 (A2-5) 2.90 8.95 2.20 2.90 Sub-step 8.25 D1 D2 D4 D1 (A3-5) 2.49 21.42 2.03 2.49

<Results>

—Recovery Percentage—

(485) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(486) [Table 28]

(487) TABLE-US-00028 TABLE 28 Recovery Recovered percentage Fraction component (%)

Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction

Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(488) The separation treatment efficiency in Example 5 was 16.502 (L-feed solution)/(L-R).Math.h.

[Example 6] Multi-Column Gradient Simulated Moving-Bed Type

(489) <Column>

(490) Five columns having a size of an inner diameter of 10 mm×a length of 80 mm

(491) <Feed Solution>

(492) The NaCl concentration in the feed solution was set to 2.55 g/L.

(493) <Eluent>

(494) The following eluents were used.

(495) [Table 29]

(496) TABLE-US-00029 TABLE 29 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2

2.55 D3 0.00 D4 2.03

<Operation Conditions>

(497) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 15. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 5 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(498) [Table 30]

(499) TABLE-US-00030 TABLE 30 Time (min.) of one step Flow velocity (mL/min.) Sub-step

5.98 D2 D4 (A1-6) 25.06 1.91 Sub-step 8.24 D1 D3 F (A2-6) 2.35 5.30 21.05 Sub-step 3.31 D1 D2

D3 (A3-6) 2.92 10.55 2.66

<Results>

—Recovery Percentage—

(500) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(501) [Table 31]

(502) TABLE-US-00031 TABLE 31 Recovery Recovered percentage Fraction component (%)

Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction

Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(503) The separation treatment efficiency in Example 6 was 18.898 (L-feed solution)/(L-R).Math.h.

[Example 7] Multi-Column Gradient Simulated Moving-Bed Type

(504) <Column>

(505) Five columns having a size of an inner diameter of 10 mm×a length of 80 mm

(506) <Feed Solution>

(507) The NaCl concentration in the feed solution was set to 2.55 g/L.

(508) <Eluent>

(509) The following eluents were used.

(510) [Table 32]

(511) TABLE-US-00032 TABLE 32 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2

2.55 D3 0.00 D4 2.03

<Operation Conditions>

(512) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 17. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 5 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(513) [Table 33]

(514) TABLE-US-00033 TABLE 33 Time (min.) of one step Flow velocity (mL/min.) Sub-step 10.39 D1 D3 F (A1-7) 2.90 4.56 18.54 Sub-step 3.66 D1 D2 D3 (A2-7) 2.90 8.95 2.20 Sub-step 8.25 D1 D2 D4 (A3-7) 2.49 21.42 2.03

<Results>

—Recovery Percentage—

(515) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(516) [Table 34]

(517) TABLE-US-00034 TABLE 34 Recovery Recovered percentage Fraction component (%) Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 98.0 Intermediately adsorptive fraction Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(518) The separation treatment efficiency in Example 7 was 16.502 (L-feed solution)/(L-R).Math.h. [Example 8] Multi-Column Gradient Simulated Moving-Bed Type

(519) <Column>

(520) Three columns having a size of an inner diameter of 10 mm×a length of 133 mm

(521) <Feed Solution>

(522) The NaCl concentration in the feed solution was set to 2.21 g/L.

(523) <Eluent>

(524) The following eluents were used.

(525) [Table 35]

(526) TABLE-US-00035 TABLE 35 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2 3.89 D3 0.46 D4 2.20

<Operation Conditions>

(527) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 19. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 3 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(528) [Table 36]

(529) TABLE-US-00036 TABLE 36 Time (min.) of one step Flow velocity (mL/min.) Sub-step 8.30 F (A1-8) 19.02 Sub-step 4.43 D2 D3 (A2-8) 10.84 10.54 Sub-step 0.35 D1 D2 D3 (A3-8) 19.31 10.84 10.54 Sub-step 4.29 D1 D2 D4 (A4-8) 19.19 4.10 17.14

<Results>

—Recovery Percentage—

(530) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(531) [Table 37]

(532) TABLE-US-00037 TABLE 37 Recovery Recovered percentage Fraction component (%) Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 Over 99 Intermediately adsorptive fraction Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(533) The separation treatment efficiency in Example 8 was 17.362 (L-feed solution)/(L-R).Math.h.
[Example 9] Multi-Column Gradient Simulated Moving-Bed Type

(534) <Column>

(535) Three columns having a size of an inner diameter of 10 mm× a length of 133 mm

(536) <Feed Solution>

(537) The NaCl concentration in the feed solution was set to 2.21 g/L.

(538) <Eluent>

(539) The following eluents were used.

(540) [Table 38]

(541) TABLE-US-00038 TABLE 38 NaCl Eluent concentration type (g/L) of eluent D1 17.53 D2 4.10 D3 0.00 D4 2.21

<Operation Conditions>

(542) The step (A) was configured by a combination of the sub-steps illustrated in FIG. 21. While this step (A) and the subsequent step (B) were set as 1 set, this was performed for 3 sets to form 1 cycle and 10 cycles were executed. The flow velocities of the eluents (D1 to D4) and the feed solution (F) supplied in each step (A) were set as described below.

(543) [Table 39]

(544) TABLE-US-00039 TABLE 39 Time (min.) of one step Flow velocity (mL/min.) Sub-step 8.14 F (A1-9) 20.58 Sub-step 4.05 D2 D3 (A2-9) 8.63 7.37 Sub-step 0.60 D2 D3 (A3-9) 8.63 7.37 Sub-step 4.09 D1 D2 D4 (A4-9) 17.65 2.67 16.50

<Results>

—Recovery Percentage—

(545) The recovery percentages for the fragments 1 and 2 into the weakly adsorptive fraction, the recovery percentage for the antibody into the intermediately adsorptive fraction, and the recovery percentage for the aggregate into the strongly adsorptive fraction are shown in the following table.

(546) [Table 40]

(547) TABLE-US-00040 TABLE 40 Recovery Recovered percentage Fraction component (%)
Weakly adsorptive fraction Fragment 1 Over 99 Fragment 2 Over 99 Intermediately adsorptive fraction Antibody 98.0 Strongly adsorptive fraction Aggregate 98.0

—Separation Treatment Efficiency—

(548) The separation treatment efficiency in Example 9 was 18.956 (L-feed solution)/(L-R).Math.h.

(549) In each of the embodiments in which the step (A) was constituted by a combination of the sub-steps shown in FIG. 23, 25, or 27, the chromatographic separation of the stock solution was attempted by a multi-column gradient simulated moving-bed type method (Example 10 to 12) in the same manner as in each of the above Examples. The following operation conditions were set such that the recovery percentages for the fragment 1 and the fragment 2 into the weakly adsorptive fraction became 98% or more, the recovery percentage for the antibody into the intermediately adsorptive fraction became 98% or more, and the recovery percentage for the aggregate into the strongly adsorptive fraction became 98% or more. As a result, in any of the embodiments, the separation treatment efficiency of 13 (L-feed solution)/(L-R).Math.h was achieved.

(550) The present invention has been described as related to the present embodiments. It is our intention that the present invention not be limited by any of the details of the description unless otherwise specified, but rather be construed broadly within its spirit and scope as set out in the attached claims.

(551) The present application claims priority of Patent Application No. 2020-085028, filed in Japan on May 14, 2020, which is herein incorporated by reference as part of the present specification.

DESCRIPTION OF SYMBOLS

(552) **100** Circulation system **10a, 10b, 10c, 10d** Unit packed column (column) Ab Adsorbent **R1, R2, R3, R4** Shutoff valve **2a, 2b, 2c, 2d** Weakly adsorptive fraction extracting line **A1, A2, A3, A4** Weakly adsorptive fraction extracting valve **3a, 3b, 3c, 3d** Intermediately adsorptive fraction

extracting line B1, B2, B3, B4 Intermediately adsorptive fraction extracting valve 4a, 4b, 4c, 4d Strongly adsorptive fraction extracting line C1, C2, C3, C4 Strongly adsorptive fraction extracting valve T1, T2, T3, T4 Check valve 1 Pipe 2J Weakly adsorptive fraction joining pipe 3J Intermediately adsorptive fraction joining pipe 4J Strongly adsorptive fraction joining pipe 6 Feed solution tank 7 Feed solution 8a, 8b, 8c, 8d Eluent tank 9a, 9b, 9c, 9d Eluent 11 Feed solution supplying line 11a, 11b, 11c, 11d F1, F2, F3, F4 Feed solution supplying valve Divergent feed solution supplying line 12, 13, 14, 15 Eluent supplying line 12a, 12b, 12c, 12d Divergent eluent supplying line 13a, 13b, 13c, 13d Divergent eluent supplying line 14a, 14b, 14c, 14d Divergent eluent supplying line 15a, 15b, 15c, 15d *Divergent eluent supplying line* E1a, E2a, E3a, E4a Eluent supplying valve E1b, E2b, E3b, E4b Eluent supplying valve E1c, E2c, E3c, E4c Eluent supplying valve E1d, E2d, E3d, E4d Eluent supplying valve P1 Circulation pump P2 Feed solution supply pump P3, P4, P5, P6 Eluent supply pump

Claims

1. A simulated moving-bed type chromatographic separation method comprising separating a weakly adsorptive component, a strongly adsorptive component, and an intermediately adsorptive component that has adsorptive property intermediate between the two components, with respect to an adsorbent, with two or more kinds of eluents by using a circulation system, the weakly adsorptive component, the strongly adsorptive component, and the intermediately adsorptive component being contained in a feed solution, wherein, in the circulation system, three or more unit packed columns each packed with an adsorbent are connected in series and in an endless form via pipes, wherein the circulation system is divided into three sections 1 to 3 provided, in an annularly continuous manner, from an upstream side to a downstream side while each section has at least one unit packed column, wherein a feed solution supply port F, two or more eluent supply ports D corresponding to the two or more kinds of eluents, an extraction port A of a weakly adsorptive fraction containing the weakly adsorptive component, an extraction port B of an intermediately adsorptive fraction containing the intermediately adsorptive component, and an extraction port C of a strongly adsorptive fraction containing the strongly adsorptive component are provided on the pipes of the circulation system, and positions of the feed solution supply port F, the extraction port A, the extraction port B, and the extraction port C are set as the following (a) to (c): (a) the extraction port B is provided on the downstream side of the feed solution supply port F with at least one section interposed therebetween; (b) the extraction port C is provided on the pipe having the feed solution supply port F or the extraction port C is provided on the upstream side of the feed solution supply port F with at least one section interposed therebetween; and (c) the extraction port A is provided on the pipe having the extraction port B or the extraction port A is provided on the downstream side of the extraction port B with at least one section interposed therebetween, and wherein the chromatographic separation method comprises, in sequence and a repeated manner, the following steps (A) and (B): [step (A)] a step of simultaneously or separately supplying the feed solution from the feed solution supply port F and the two or more kinds of eluents from the two or more eluent supply ports D, respectively, and simultaneously or separately extracting the weakly adsorptive fraction from the extraction port A, the intermediately adsorptive fraction from the extraction port B, and the strongly adsorptive fraction from the extraction port C, respectively; and [step (B)] a step of shifting the feed solution supply port F, the eluent supply ports D, the extraction port A, the extraction port B, and the extraction port C to the downstream side, while maintaining a relative positional relationship therebetween after finishing the step (A).

2. The simulated moving-bed type chromatographic separation method according to claim 1, wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-8), (A2-8), (A3-8), and (A4-8): <sub-step (A1-8)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 2 as the feed solution supply

port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 3 as the extraction port A; <sub-step (A2-8)> supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 2 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1; <sub-step (A3-8)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying the eluent d-II from the eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying the eluent d-III from the eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2; and <sub-step (A4-8)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 2 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

3. The simulated moving-bed type chromatographic separation method according to claim 1, wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-9), (A2-9), (A3-9), and (A4-9): <sub-step (A1-9)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 3 as the extraction port A; <sub-step (A2-9)> supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 1 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 2 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1; <sub-step (A3-9)> supplying the eluent d-II from the eluent supply port D-II, supplying the eluent d-III from the eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the sections 1 and 2, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the sections 1 and 2; and <sub-step (A4-9)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the strongly adsorptive fraction extraction port C, supplying the

eluent d-II from the eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 2 as the intermediately adsorptive fraction extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

4. The simulated moving-bed type chromatographic separation method according to claim 1, wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-10), (A2-10), (A3-10), and (A4-10): <sub-step (A1-10)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 2 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 3 as the extraction port A; <sub-step (A2-10)> supplying an eluent d-IV having desorption strength equal to or stronger than the feed solution from an eluent supply port D-IV while using an upstream end of the section 2 as the eluent supply port D-IV and extracting the weakly adsorptive fraction from the extraction port A; <sub-step (A3-10)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 3 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2; and <sub-step (A4-10)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 2 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the section 2 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the section 3 more than the desorption strength of the eluent passing through the section 2.

5. A simulated moving-bed type chromatographic separation method including separating a weakly adsorptive component, a strongly adsorptive component, and an intermediately adsorptive component that has adsorptive property intermediate between the two components, with respect to an adsorbent, with two or more kinds of eluents by using a circulation system, the weakly adsorptive component, the strongly adsorptive component, and the intermediately adsorptive component being contained in a feed solution, wherein, in the circulation system, five or more unit packed columns each packed with the adsorbent are connected in series and in an endless form via pipes, wherein the circulation system is divided into five sections 1 to 5 provided, in an annularly continuous manner, from an upstream side to a downstream side while each section has at least one unit packed column, wherein a feed solution supply port F, two or more eluent supply ports D

corresponding to the two or more kinds of eluents, an extraction port A of a weakly adsorptive fraction containing the weakly adsorptive component, an extraction port B of an intermediately adsorptive fraction containing the intermediately adsorptive component, and an extraction port C of a strongly adsorptive fraction containing the strongly adsorptive component are provided on the pipes of the circulation system, and positions of the feed solution supply port F, the extraction port A, the extraction port B, and the extraction port C are set as the following (a) to (c): (a) the extraction port B is provided on the downstream side of the feed solution supply port F with at least one section interposed therebetween; (b) the extraction port C is provided on the pipe having the feed solution supply port F or the extraction port C is provided on the upstream side of the feed solution supply port F with at least one section interposed therebetween; and (c) the extraction port A is provided on the pipe having the extraction port B or the extraction port A is provided on the downstream side of the extraction port B with at least one section interposed therebetween, and wherein the chromatographic separation method comprises, in sequence and a repeated manner, the following steps (A) and (B): [step (A)] a step of simultaneously or separately supplying the feed solution from the feed solution supply port F and the two or more kinds of eluents from the two or more eluent supply ports D, respectively, and simultaneously or separately extracting the weakly adsorptive fraction from the extraction port A, the intermediately adsorptive fraction from the extraction port B, and the strongly adsorptive fraction from the extraction port C, respectively; and [step (B)] a step of shifting the feed solution supply port F, the eluent supply ports D, the extraction port A, the extraction port B, and the extraction port C to the downstream side, while maintaining a relative positional relationship therebetween after finishing the step (A).

6. The simulated moving-bed type chromatographic separation method according to claim 5, wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-11), (A2-11), and (A3-11): <sub-step (A1-11)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 5 as the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 3, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the section 3; <sub-step (A2-11)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying the eluent d-III from the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3; and <sub-step (A3-11)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 3 as the extraction port B, supplying an eluent d-IV from an eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections

4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.

7. The simulated moving-bed type chromatographic separation method according to claim 5, wherein, in the step (A), the two or more kinds of eluents are used to perform the following sub-steps (A1-12), (A2-12), (A3-12), and (A4-12): <sub-step (A1-12)> supplying a feed solution from the feed solution supply port F while using an upstream end of the section 3 as the feed solution supply port F and extracting the weakly adsorptive fraction from the extraction port A while using a downstream end of the section 5 as the extraction port A; <sub-step (A2-12)> supplying an eluent d-IV having desorption strength equal to or stronger than the feed solution from an eluent supply port D-IV while using an upstream end of the section 3 as the eluent supply port D-IV and extracting the weakly adsorptive fraction from the extraction port A; <sub-step (A3-12)> supplying an eluent d-I from an eluent supply port D-I while using an upstream end of the section 1 as the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C while using a downstream end of the section 1 as the extraction port C, supplying an eluent d-II from an eluent supply port D-II while using an upstream end of the section 2 as the eluent supply port D-II, supplying an eluent d-III from an eluent supply port D-III while using an upstream end of the section 4 as the eluent supply port D-III, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3; and <sub-step (A4-12)> supplying the eluent d-I from the eluent supply port D-I, extracting the strongly adsorptive fraction from the extraction port C, supplying the eluent d-II from the eluent supply port D-II, extracting the intermediately adsorptive fraction from the extraction port B while using a downstream end of the section 3 as the extraction port B, supplying the eluent d-IV from the eluent supply port D-IV while using an upstream end of the section 4 as the eluent supply port D-IV, and extracting the weakly adsorptive fraction from the extraction port A, thereby most strengthening strongest desorption strength of the eluent passing through the section 1, weakening desorption strength of the eluent passing through the sections 2 and 3 more than the desorption strength of the eluent passing through the section 1, and weakening desorption strength of the eluent passing through the sections 4 and 5 more than the desorption strength of the eluent passing through the sections 2 and 3.
