Description

Title of Invention: WATER ABSORBENT AND METHOD FOR MANUFACTURING WATER ABSORBENT

Technical Field

[0001]

The present invention relates to a water absorbent and a method for producing a water absorbent.

Background Art

[0002]

At present, in sanitary materials such as disposable diapers, sanitary napkins, and so-called incontinence pads, mixtures containing a water-absorbent resin and hydrophilic fibers such as pulp for the purpose of absorbing body fluids are widely used as constituent materials thereof. On the other hand, in recent years, in order to further improve water absorption performance of the sanitary materials, development of applying a water absorbent more excellent in water absorption speed for a constituent material of the sanitary materials has been advanced.

[0003]

Here, as the water absorbent, for example, a monolithic organic porous ion exchanger (water absorbent) having a continuous skeleton and continuous pores as described in Patent Document 1 is known. The monolithic organic porous ion exchanger is a hydrolysate produced by hydrolyzing a crosslinked polymer of a (meth)acrylic acid ester and a compound having two or more vinyl groups in one molecule.

[0004]

As a water absorbent having a continuous skeleton and continuous pores, which is produced by a method other than the hydrolysis, for example, water-absorbent polymer particles as described in Patent Document 2 are known. The water-absorbent polymer particles are specifically produced by a method including the following steps (a) and (b).

[0005]

(a) Step of incorporating a first solvent into an aqueous solution of a water-soluble ethylenically unsaturated monomer in the presence of a first surfactant to obtain an O/W emulsion

(b) Step of dispersing the O/W emulsion obtained in step (a) in a second solvent containing a second surfactant to obtain an O/W/O emulsion

Citation List

Patent Document

[0006]

Patent Document 1: JP 2021-007900 A

Patent Document 2: JP 2006-342306 A

Summary of Invention

Technical Problem

[0007]

On the other hand, the monolithic organic porous ion exchanger described in Patent Document 1 is a hydrolysate, and an excessive amount of an alkali component is used during production, and (meth)acrylic acid as a constituent component is neutralized 100% by the alkali component. Therefore, the alkali component remains in the pores of the monolithic organic porous ion exchanger even after washing. Therefore, the monolithic organic porous ion exchanger has a pH value of more than 8, and therefore may cause, for example, skin roughness of a user.

[0008]

In addition, the water-absorbent polymer particles described in Patent Document 2 have room for improvement in water absorption speed. In addition, a water absorbent that can be used as a constituent material of a sanitary material is required to be excellent in water separation percentage in addition to water absorption speed. Here, the term "excellent in water separation percentage" means that, when a pressure is applied to a water absorbent that has absorbed an aqueous liquid and has been swelling, the absorbed aqueous liquid is more easily released in a larger amount.

[0009]

An object of an embodiment of the present invention is to solve the above-described issue and to provide a water absorbent that can reduce skin roughness and the like of a user, as compared with known water absorbents, and is excellent in water absorption speed and water separation percentage.

Solution to Problem

[0010]

The present inventors have found that the above-described issue can be solved by a water absorbent including an organic porous body formed from a crosslinked polymer having a rate of neutralization adjusted to be reduced compared to known water absorbents and having a specific porous structure inside in which water retention ability and bulk specific gravity fall within specific ranges. The present inventors have also found that, in the production method described in Patent Document 2, a water absorbent including an organic porous body having the specific porous structure inside can be obtained by controlling a volume ratio (O/W volume ratio) of the first solvent to the aqueous solution of the unsaturated monomer to 2.5 or more.

[0011]

That is, an embodiment of the present invention provides a water absorbent including an organic porous body, the organic porous body containing continuous pores and a continuous

skeleton formed of a crosslinked polymer, the crosslinked polymer containing a structural unit derived from (meth)acrylic acid (salt) as a main component, wherein

a centrifuge retention capacity (CRC) is from 5 to 25 g/g;

a bulk specific gravity is less than 0.3 g/ml; and

a rate of neutralization of the crosslinked polymer is less than 70 mol%.

[0012]

Another embodiment of the present invention provides a method for producing a water absorbent, the water absorbent including an organic porous body containing continuous pores and a continuous skeleton formed of a crosslinked polymer, the crosslinked polymer containing a structural unit derived from (meth)acrylic acid (salt) as a main component, the method including:

an O/W emulsion preparation step of incorporating a first solvent, with a first surfactant, into an aqueous monomer solution having a rate of neutralization of less than 70 mol% in a way that a volume ratio of the first solvent to the aqueous monomer solution is 2.5 or more to obtain an O/W emulsion;

an O/W/O emulsion preparation step of dispersing the O/W emulsion in a second solvent to obtain an O/W/O emulsion; and

a polymerization step of polymerizing, in the O/W/O emulsion, a monomer contained in the aqueous monomer solution to prepare the organic porous body.

Advantageous Effects of Invention

[0013]

The water absorbent according to an embodiment of the present invention can reduce skin roughness and the like of a user, as compared with known water absorbents, and is excellent in both water absorption speed and water separation percentage. Further, the method for producing a water absorbent according to an embodiment of the present invention has an effect that the water absorbent can be produced.

Brief Description of Drawings

[0014]

FIG. 1 is a schematic view illustrating an aspect of an O/W/O emulsion preparation step and a polymerization step of the method for producing a water absorbent according to an embodiment of the present invention.

Description of Embodiments

[0015]

An embodiment of the present invention will be described below, but the present invention is not limited thereto. The present invention is not limited to the configurations described below, and various modifications can be made within the scope set forth by the claims. Moreover, embodiments obtained by appropriately combining technical means disclosed in

different embodiments are also included in the technical scope of the present invention. In the present specification, a numerical range described as "from A to B" means "A or more and B or less" unless otherwise specified.

[0016]

1. Definition of Terms

1-1. Crosslinked Polymer

In the present specification, the "crosslinked polymer" specifically refers to a polymeric gelling agent having a water-swellable capacity (CRC), as defined by NWSP 241.0.R2 (15), of 5 g/g or more and a water-soluble component (Ext), as defined by NWSP 270.0.R2 (15), of 70 mass% or less.

[0017]

"NWSP" is an abbreviation of "Non-Woven Standard Procedures - Edition 2015". The NWSP was issued jointly by the European Disposables And Nonwovens Association (EDANA) and the Association of the Nonwoven Fabrics Industry (INDA) in the United States and Europe to standardize methods for evaluating nonwoven fabrics and products thereof, and includes standard measurement methods for water-absorbent resins. In the present specification, unless otherwise specified, the physical properties of the crosslinked polymer and water absorbent are measured in accordance with the NWSP.

[0018]

In the present specification, the "crosslinked polymer" is not limited to an embodiment in which the entire amount (100 mass%) consists only of the crosslinked polymer, and may be a composition generally referred to as "water-absorbent resin composition" containing an additive or the like. In addition, in the present specification, the "crosslinked polymer" may include a crosslinked polymer being a hydrogel in which water is taken therein.

[0019]

1-2. Water Absorbent

In the present specification, the "water absorbent" is a material that has an ability to absorb and retain a solution (liquid) and contains continuous pores and a continuous skeleton formed of, as a main component, a crosslinked polymer. In particular, the water absorbent can be used as an absorbent body in combination with a particulate superabsorbent polymer having excellent water absorption performance, which is generally called a water-absorbent resin. The water absorbent of the present invention is a material characterized by temporarily retaining a liquid and delivering the liquid to the superabsorbent polymer at that time. Here, the solution (liquid) is not particularly limited as long as it is a liquid, not only water. The liquid absorbed by the water absorbent according to an embodiment of the present invention is, for example, urine, menstrual blood, sweat, physiological saline, oil, an organic solvent, or a waste liquid.

[0020]

The water absorbent described in the present specification may be a particulate (powdery) water absorbent, that is, a water absorbent generally referred to as "particulate water

absorbent". The particulate water absorbent contains a crosslinked polymer as a main component, and therefore corresponds to a particulate crosslinked polymer. The concept of "particulate water absorbent" includes both a single particle of particulate water absorbent and an aggregate of a plurality of particles of particulate water absorbent. In the present specification, the "particulate" means having a form of particles. In the present specification, the "particle" refers to a relatively small divided body of a substance, and has a size of several Å to several mm (see "Particle" in "McGraw-Hill Dictionary of Scientific and Technical Terms, 3rd edition", edited by McGraw-Hill Dictionary of Scientific and Technical Terms Editorial Committee, Nikkan Kogyo Shimbun, Ltd., 1996, p. 1929). In the present specification, the “particulate water absorbent” is sometimes simply referred to as “water absorbent”.

[0021]

The water absorbent contains a crosslinked polymer (or also referred to as particulate crosslinked polymer) as a main component. The water absorbent contains from 60 to 100 mass%, preferably from 70 to 95 mass%, and more preferably from 75 to 90 mass% of a crosslinked polymer. The remainder of the water absorbent may optionally contain water and/or an additive (such as an inorganic fine particle or a polyvalent metal cation).

[0022]

That is, an upper limit of the content of the crosslinked polymer in the water absorbent is, for example, 100 mass%, 90 mass%, 80 mass%, or 70 mass%. The water absorbent preferably further contains from 5 to 30 mass% of a component other than the crosslinked polymer, particularly water and/or an additive (such as an inorganic fine particle or a polyvalent metal cation).

[0023]

A preferable moisture content of the water absorbent is from 0.2 to 30 mass%. As described above, the "particulate water absorbent" also includes a composition containing a crosslinked polymer in a state where a component such as water and/or an additive is integrated with and/or mixed with the crosslinked polymer. In the present specification, the "moisture content" is a numerical value indicating a proportion of a mass of water contained in a measurement target to a mass of the entire measurement target, more specifically, a mass of the entire measurement target in a state of containing water, and can be determined based on the following Formula (2). Examples of the measurement target include the water absorbent, an organic porous body described later, a crosslinked polymer described later, and a hydrogel described later, and their moisture content can be determined in the same manner.

[Moisture content (mass%) of measurement target] = [(Mass of water in measurement target) ÷ (Mass of the entire measurement target)] × 100 ⋯ (2)

2. Water Absorbent

The water absorbent according to an embodiment of the present invention (hereinafter referred to as "water absorbent of the present invention") is a water absorbent including an organic porous body having continuous pores and a continuous skeleton formed of a crosslinked

polymer, the crosslinked polymer containing, as a main component, a structural unit derived from (meth)acrylic acid (salt). In the water absorbent, a centrifuge retention capacity (CRC) is from 5 to 25 g/g; a bulk specific gravity is less than 0.3 g/ml; and a rate of neutralization of the crosslinked polymer is less than 70 mol%.

[0024]

In the water absorbent of the present invention, the rate of neutralization of the crosslinked polymer is less than 70 mol%. Therefore, the water absorbent of the present invention is adjusted to be weakly acidic and can reduce, for example, skin roughness and the like of a user of the water absorbent as compared with known water absorbents.

[0025]

The water absorbent of the present invention includes the organic porous body that has the continuous pores and the continuous skeleton formed of the crosslinked polymer, and thus, when the water absorbent absorbs a liquid such as water, the liquid is retained inside the continuous pores and the crosslinked polymer.

[0026]

The aforementioned CRC means an amount of a liquid remaining in a water absorbent after a specific centrifugal force (pressure) is applied to the water absorbent in a swollen state formed by having absorbed the liquid and a part of the liquid is released. When the centrifugal force is applied, the liquid retained inside the continuous pores is almost released from the swollen water absorbent. Therefore, the CRC is nearly the amount of the liquid retained inside the crosslinked polymer of the water absorbent in a swollen state.

[0027]

The bulk specific gravity is a parameter representing a mass per unit volume of the water absorbent. The mass is mainly a mass of the crosslinked polymer constituting the water absorbent per unit volume. Therefore, the bulk specific gravity is a parameter representing a proportion of a portion occupied by the continuous skeleton to a portion occupied by the continuous pores in the entire water absorbent. That is, the fact that the bulk specific gravity is small means that the portion occupied by the continuous skeleton is small and that the portion occupied by the continuous pores is large in the entire water absorbent.

[0028]

The water absorbent of the present invention has a CRC of 25 g/g or less and a bulk specific gravity controlled to less than 0.3 g/ml. Therefore, the water absorbent of the present invention has a structure in which the portion occupied by the continuous pores is large. The structure is more likely to take the liquid therein and to release the liquid when a centrifugal force (pressure) is applied. Therefore, the water absorbent of the present invention is excellent in both water absorption speed and water separation percentage.

[0029]

The water absorbent of the present invention has a CRC of 5 g/g or more. This means that the water absorbent of the present invention includes a portion occupied by the continuous

skeleton in a predetermined amount. Therefore, the water absorbent of the present invention has a predetermined water absorption performance.

[0030]

As described above, the water absorbent of the present invention can reduce skin roughness and the like of a user of the water absorbent as compared with known water absorbents, and is excellent in both water absorption speed and water separation percentage.

[0031]

Patent Document 2 describes that a water absorbent including an organic porous body having a small bulk specific gravity is insufficient in mechanical strength. On the other hand, the mechanical strength of the water absorbent of the present invention was confirmed by a method (damage test) of putting the water absorbent and glass beads in a glass container and then shaking the container, and it was confirmed that the water absorbent of the present invention had sufficient mechanical strength for use as a water absorbent. The method is a technique of simulating mechanical damage caused in a production process in a chemical plant or the like.

[0032]

Hereinafter, each member constituting the water absorbent of the present invention and the characteristics of the water absorbent of the present invention will be described in detail.

[0033]

2-1. Crosslinked Polymer

The crosslinked polymer contained in the water absorbent of the present invention is a crosslinked polymer containing, as a main component, a structural unit derived from (meth)acrylic acid (salt). Specifically, the crosslinked polymer is a hydrophilic crosslinked polymer obtained by crosslinking and polymerizing a monomer composition containing a (meth)acrylic acid (salt)-based monomer, that is, a poly(meth)acrylic (acid)-based crosslinked polymer.

[0034]

In the present specification, the "(meth)acrylic acid (salt)" refers to (meth)acrylic acid and/or a salt thereof. The "monomer composition containing a (meth)acrylic acid (salt)-based monomer" means a monomer composition containing 50 mol% or more of (meth)acrylic acid (salt) with respect to a total amount of monomers excluding a crosslinking agent.

[0035]

The crosslinked polymer contained in the water absorbent of the present invention is a crosslinked polymer containing 50 mol% or more of a structural unit derived from (meth)acrylic acid (salt) with respect to a total amount of structural units constituting the poly(meth)acrylic acid (salt)-based crosslinked polymer, and is a crosslinked polymer having a structural unit derived from an internal crosslinking agent as an optional component.

[0036]

The crosslinked polymer is constituted of 50 mol% or more, preferably 70 mol% or more, and more preferably 90 mol% or more of (meth)acrylic acid (salt), relative to the amount

of constituent components excluding the internal crosslinking agent. The crosslinked polymer is constituted of, preferably 100 mol% or less, more preferably substantially 100 mol%, of (meth)acrylic acid (salt), relative to the amount of constituent components excluding the internal crosslinking agent.

[0037]

The crosslinked polymer contained in the water absorbent of the present invention may have, for example, a particulate shape. The particulate crosslinked polymer may have, for example, one or more shapes selected from the group consisting of an irregularly crushed shape (irregular shape), a spherical shape, a fibrous shape, a rod shape, a substantially spherical shape, and a flat shape. Among these, at least a part of the crosslinked polymer is preferably spherical particles. In consideration of damage in the production process, the crosslinked polymer is more preferably spherical particles among the above-described particle shapes from the viewpoint of a decrease in productivity due to generation of fine powder. The particulate crosslinked polymer is referred to as particulate crosslinked polymer in both cases where the particulate crosslinked polymer is a single particle and where the particulate crosslinked polymer is an aggregate of a plurality of particles. The crosslinked polymer is a porous body.

[0038]

Monomer and Monomer Composition

In the present specification, the "monomer composition" refers to a raw material component that forms the crosslinked polymer and refers to a composition containing (meth)acrylic acid (salt) as a main component of the monomer, and further containing a monomer other than the (meth)acrylic acid (salt), and an internal crosslinking agent as an optional component. That is, the raw material component constituting the crosslinked polymer is referred to as monomer composition.

[0039]

As the monomer other than the (meth)acrylic acid (salt), a monomer containing an acid group is preferable among monomers having an unsaturated double bond (ethylenically unsaturated monomers). Specific examples of the monomer include anionic unsaturated monomers such as maleic acid (maleic anhydride), fumaric acid, crotonic acid, itaconic acid, cinnamic acid, vinyl sulfonic acid, allyl toluene sulfonic acid, vinyl toluene sulfonic acid, styrene sulfonic acid, 2-(meth)acrylamide-2-methylpropane sulfonic acid, 2-(meth)acryloyl ethane sulfonic acid, 2-(meth)acryloyl propane sulfonic acid, and 2-hydroxyethyl (meth)acryloyl phosphate, and/or salts thereof. One of, or two or more of these monomers are used as necessary.

[0040]

Examples of the salt include one or more salts selected from the group consisting of an alkali metal salt, an ammonium salt, and an amine salt. A sodium salt, a potassium salt, a lithium salt, or an ammonium salt is more preferable, and a sodium salt is particularly preferable.

[0041]

The rate of neutralization of the crosslinked polymer contained in the water absorbent of the present invention can be controlled by the rate of neutralization of the monomer composition. Further, adjustment may be performed by adding a neutralizing agent to the crosslinked polymer or the water absorbent after the polymerization step. The rate of neutralization is a proportion (unit: mol%) of the number of moles of neutralized monomers to the number of moles of all monomers (excluding the internal crosslinking agent) constituting the crosslinked polymer.

[0042]

The rate of neutralization of the water absorbent of the present invention is a small value of less than 70 mol%, and therefore, as described above, the water absorbent of the present invention can reduce skin roughness and the like of a user of the water absorbent as compared with known water absorbents. From this viewpoint, the rate of neutralization is preferably 65 mol% or less.

[0043]

In addition, when the rate of neutralization is equal to or more than a predetermined value, the water absorption performance such as the fluid retention capacity and water absorption speed of the water absorbent of the present invention can be improved. From this viewpoint, the rate of neutralization is preferably 30 mol% or more, and more preferably 40 mol% or more.

[0044]

As necessary, the monomer composition may contain "a hydrophilic or hydrophobic unsaturated monomer (hereinafter, referred to as 'additional monomer')" in addition to the "(meth)acrylic acid (salt)" and the "monomer other than (meth)acrylic acid (salt)" described above.

[0045]

Examples of the additional monomer include sulfanyl group-containing unsaturated monomers; phenolic hydroxyl group-containing unsaturated monomers; amide group-containing unsaturated monomer such as N-vinyl-2-pyrrolidone, N-vinylacetamide, (meth)acrylamide, N-isopropyl(meth)acrylamide, N-ethyl(meth)acrylamide, and N,N-dimethyl(meth)acrylamide; and amino group-containing unsaturated monomers such as N,N-dimethylaminoethyl (meth)acrylate, N,N-dimethylaminopropyl (meth)acrylate, and N,N-dimethylaminopropyl (meth)acrylamide. One or more of the additional monomers can be used.

[0046]

The amount of the additional monomer to be used is not particularly limited as long as the physical properties of the resulting water absorbent are not impaired, and is specifically 50 mol% or less, more preferably 20 mol% or less with respect to the amount of the monomer composition excluding the internal crosslinking agent.

[0047]

Internal Crosslinking Agent

The crosslinked polymer is crosslinked. The crosslinking may be a self-crosslinking type without using a crosslinkable monomer. On the other hand, the crosslinked polymer is preferably

internally crosslinked by an internal crosslinking agent from the viewpoint of physical properties.

[0048]

The internal crosslinking agent is preferably at least one selected from the group consisting of a polyfunctional acrylate-based crosslinking agent, a polyfunctional acrylamide-based crosslinking agent, and a polyfunctional glycidyl ether-based crosslinking agent.

[0049]

Specific examples of the internal crosslinking agent include N,N′-methylenebis(meth)acrylamide, (poly)ethylene glycol di(meth)acrylate, (poly)propylene glycol di(meth)acrylate, trimethylolpropane di(meth)acrylate, trimethylolpropane tri(meth)acrylate, glycerin tri(meth)acrylate, glycerin acrylate methacrylate, ethylene oxide-modified trimethylolpropane tri(meth)acrylate, pentaerythritol tetra(meth)acrylate, dipentaerythritol hexa(meth)acrylate, triallyl cyanurate, triallyl isocyanurate, triallyl phosphate, triallylamine, poly(meth)allyloxyalkane, (poly)ethylene glycol diglycidyl ether, glycerol diglycidyl ether, ethylene glycol, polyethylene glycol, propylene glycol, glycerin, pentaerythritol, ethylenediamine, polyethyleneimine, and glycidyl (meth)acrylate. Among these internal crosslinking agents, at least one internal crosslinking agent is selected in consideration of reactivity and the like.

[0050]

In the present invention, an internal crosslinking agent having two or more polymerizable unsaturated groups is preferably selected from the viewpoint of the water absorption performance of the crosslinked polymer and the water absorbent of the present invention.

[0051]

Specific examples of the polymerizable unsaturated group include an allyl group and a (meth)acryloyl group. Among the polymerizable unsaturated groups, a (meth) acryloyl group is preferable. Among them, an internal crosslinking agent having two or more polymerizable unsaturated groups having a (poly)alkylene glycol structure can be used, and examples thereof include polyethylene glycol di(meth)acrylate. The number of alkylene glycol units in the internal crosslinking agent is preferably 1 or more, more preferably 2 or more, still more preferably 4 or more, and particularly preferably 6 or more. The number of the alkylene glycol units is preferably 100 or less, more preferably 50 or less, still more preferably 20 or less, and particularly preferably 10 or less.

[0052]

A content of the internal crosslinking agent is preferably 0.001 mol% or more, more preferably 0.01 mol% or more, and still more preferably 0.1 mol% or more with respect to the amount of the monomer composition excluding the internal crosslinking agent. The content of the internal crosslinking agent is preferably 10 mol% or less, more preferably 7 mol% or less, and still more preferably 5 mol% or less with respect to the amount of the monomer composition excluding the internal crosslinking agent.

[0053]

When the content of the internal crosslinking agent is within the range, the water absorption performance of the crosslinked polymer and the water absorbent of the present invention can be adjusted to fall within a desired range. On the other hand, when the content of the internal crosslinking agent is out of the above range, the water-soluble content of the crosslinked polymer may increase or the retention capacity of the crosslinked polymer and the water absorbent of the present invention may decrease, as gel strength of the crosslinked polymer decreases.

[0054]

Surface-Crosslinking Agent

The crosslinked polymer may be surface-crosslinked and may have a surface-crosslinked layer. The surface-crosslinked layer may be formed on the surface of the crosslinked polymer by surface-crosslinking performed using a surface-crosslinking agent described in US 7183456. Among these surface-crosslinking agents, at least one surface-crosslinking agent is selected in consideration of reactivity and the like. In addition, from the viewpoint of the ease of handling of the surface-crosslinking agent, the water absorption performance of the water absorbent, and the like, an organic compound in which a covalent bond is formed and contains two or more functional groups reactive with a carboxyl group is preferably selected as the surface-crosslinking agent.

[0055]

Examples of the surface-crosslinking agent include polyhydric alcohol compounds such as ethylene glycol, diethylene glycol, triethylene glycol, tetraethylene glycol, polyethylene glycol, propylene glycol, dipropylene glycol, polypropylene glycol, 1,3-propanediol, 1,2-butanediol, 1,3-butanediol, 1,4-butanediol, 2,3-butanediol, 1,2-pentanediol, 1,3-pentanediol, 1,4-pentanediol, 1,5-pentanediol, 2,3-pentanediol, 2,4-pentanediol, 1,2-hexanediol, 1,3-hexanediol, 1,4-hexanediol, 1,5-hexanediol, 1,6-hexanediol, 2,3-hexanediol, 2,4-hexanediol, glycerin, polyglycerin, diethanolamine, and triethanolamine; polyvalent amine compounds such as ethylenediamine, diethylenetriamine, triethylenetetramine, tetraethylenepentamine, pentaethylenehexamine, polyallylamine, and polyethyleneimine; haloepoxy compounds; condensates of polyvalent amine compounds and haloepoxy compounds; oxazoline compounds such as 1,2-ethylenebisoxazoline; oxazolidinone compounds; alkylene carbonate compounds such as 1,3-dioxolan-2-one(ethylene carbonate), 4-methyl-1,3-dioxolan-2-one, 4,5-dimethyl-1,3-dioxolan-2-one, 4,4-dimethyl-1,3-dioxolan-2-one, 4-ethyl-1,3-dioxolan-2-one, 4-hydroxymethyl-1,3-dioxolan-2-one, 1,3-dioxan-2-one, 4-methyl-1,3-dioxan-2-one, 4,6-dimethyl-1,3-dioxan-2-one, and 1,3-dioxopan-2-one; polyvalent glycidyl compounds such as ethylene glycol diglycidyl ether, polyethylene diglycidyl ether, propylene glycol diglycidyl ether, polypropylene glycol diglycidyl ether, glycerol polyglycidyl ether, diglycerol polyglycidyl ether, polyglycerol polyglycidyl ether, and glycidol; oxetane compounds; vinyl ether compounds; and cyclic urea compounds. One of these surface crosslinking agents may be used alone, or two or more thereof may be used in combination.

[0056]

2-2. Organic Porous Body

The organic porous body of the present invention has continuous pores and a continuous skeleton formed of the crosslinked polymer. In other words, the organic porous body is an organic porous body formed from the crosslinked polymer, and may have a particulate shape. Therefore, the organic porous body may be the particulate crosslinked polymer.

[0057]

A thickness of the continuous skeleton of the organic porous body is preferably 0.1 μm or more, more preferably 0.5 μm or more, and still more preferably 1 μm or more in a dry state. When the thickness is equal to or more than the lower limit value, the strength of the organic porous body and the water absorbent itself of the present invention can be improved.

[0058]

The thickness is preferably 100 μm or less, more preferably 50 μm or less, and still more preferably 10 μm or less. When the thickness is equal to or less than the upper limit value, the absorption speed of the water absorbent of the present invention for a liquid such as water can be improved.

[0059]

In the measurement of the thickness of the continuous skeleton of the organic porous body in a dry state, the skeleton cross section appearing in a test piece for electron microscopic measurement of the water absorbent of the present invention is used as a site for evaluation of the thickness, because the pore structure of the organic porous body is an open-cell structure. The open-cell structure is a structure in which bubble-shaped macropores are overlapped with each other.

[0060]

An average size of the continuous pores of the organic porous body in a dry state is preferably 0.1 μm or more, more preferably 1.0 μm or more, and still more preferably 2.0 μm or more. When the average size is equal to or more than the lower limit value, the absorption speed of the water absorbent of the present invention for a liquid such as water can be improved.

[0061]

In addition, the average size of the continuous pores of the organic porous body in a dry state is preferably 1000 μm or less, more preferably 100 μm or less, and still more preferably 50 μm or less. When the average size is equal to or less than the upper limit value, the strength of the organic porous body and the water absorbent itself of the present invention can be improved.

[0062]

As a sample for measuring the thickness of the continuous skeleton and the average size of the continuous pores, a sample obtained by drying the water absorbent of the present invention at 50°C for 18 hours or more by a vacuum dryer is used. At this time, a final arrival pressure is set to 0 Torr.

[0063]

2-3. Surfactant

The water absorbent of the present invention can be produced by the method for producing a water absorbent according to an embodiment of the present invention as described later. Therefore, a surfactant used in the production method remains, and thus the surfactant may be contained in the water absorbent of the present invention.

[0064]

The surfactant may be, for example, a surfactant exemplified as a specific example in the "First Surfactant " and the "Second Surfactant " below. A single type of the surfactants may be used alone, or a mixture with two or more types thereof may be used.

[0065]

An upper limit value of a content of the surfactant is preferably 15 parts by mass or less, and more preferably 10 parts by mass or less, with respect to 100 parts by mass of the crosslinked polymer. When the upper limit value of the content of the surfactant is the above-described value or less, a decrease in the water absorption performance due to the surfactant remaining in the water absorbent of the present invention can be prevented, and the water absorption performance such as the water absorption speed can be improved. A lower limit value of the content of the surfactant is not particularly limited, but may be, for example, 0.045 parts by mass or more, and is preferably 0.090 parts by mass or more with respect to 100 parts by mass of the crosslinked polymer.

[0066]

2-4. Chelating Agent

The water absorbent of the present invention may contain a chelating agent. The chelating agent may be, for example, a polyvalent carboxylic acid and a salt thereof. The chelating agent is preferably a chelating agent having high ion sequestering ability and chelating ability for Fe or Cu. The chelating agent is specifically a chelating agent having a stability constant for Fe ions of 10 or more, preferably 20 or more, and more preferably an amino polyvalent carboxylic acid and a salt thereof. The amino polyvalent carboxylic acid and the salt thereof may be polymers. The amino polyvalent carboxylic acid and the salt thereof are particularly preferably an aminocarboxylic acid and a salt thereof having a lower limit of the number of carboxyl groups of 3 or more, preferably 4 or more, and more preferably 5 or more, and an upper limit of the number of carboxyl groups of usually 100 or less, more preferably 20 or less.

[0067]

Examples of the polyvalent carboxylic acid include diethylenetriaminepentaacetic acid, triethylenetetraaminehexaacetic acid, cyclohexane-1,2-diaminetetraacetic acid, N-hydroxyethylethylenediaminetriacetic acid, ethylene glycol diethyl ether diaminetetraacetic acid, ethylenediaminetetrapropionacetic acid, N-alkyl-N′-carboxymethylaspartic acid, and N-alkenyl-N′-carboxymethylaspartic acid, and alkali metal salts, alkaline earth metal salts, ammonium salts, and amine salts thereof. Among these polyvalent carboxylic acids, diethylenetriaminepentaacetic

acid, triethylenetetraaminehexaacetic acid, N-hydroxyethylethylenediaminetriacetic acid, and salts thereof are most preferable. One or more of the polyvalent carboxylic acids can be used.

[0068]

A content of the chelating agent, particularly the amino polyvalent carboxylic acid, is a trace component, usually from 0.00001 to 10 parts by mass, preferably from 0.0001 to 1 part(s) by mass, and more preferably from 0.01 to 0.5 parts by mass, with respect to 100 parts by mass of the crosslinked polymer.

[0069]

At this time, a sufficient effect and/or additional function due to addition of the chelating agent can be obtained, and the absorption performance of the water absorbent can be maintained.

[0070]

2-5. Inorganic Fine Particle

The water absorbent of the present invention may contain inorganic fine particles, particularly water-insoluble inorganic fine particles, for the purpose of preventing blocking during moisture absorption. Examples of the inorganic fine particles include one or more selected from the group consisting of metal oxides such as silicon dioxide and titanium oxide, silicic acids (salts) such as natural zeolite and synthetic zeolite, kaolin, talc, clay, and bentonite. Among these inorganic fine particles, silicon dioxide and silicic acid (salt) are more preferable, and silicon dioxide and silicic acid (salt) having an average particle size of 0.001 to 200 μm as measured by a Coulter counter method are still more preferable. In addition, a deodorizing function may be imparted to the water absorbent of the present invention by incorporating zeolite, and zeolite having a blending ratio of SiO_2:Al_2O_3 of 1:1 to 100, preferably 1:2 to 10 is preferable.

[0071]

A content of the inorganic fine particles is usually in a range from 0 to 10 parts by mass, preferably from 0.001 to 5 parts by mass, and more preferably from 0.002 to 3 parts by mass, with respect to 100 parts by mass of the crosslinked polymer.

[0072]

At this time, a sufficient effect and/or additional function due to addition of the inorganic fine particles can be obtained, and the absorption performance of the water absorbent can be maintained.

[0073]

2-6. Additional Additive

The water absorbent of the present invention may contain an additional additive other than the surfactant, the chelating agent, and the inorganic fine particles as long as the object of the present invention is not impaired.

[0074]

Examples of the additional additive can include plant components, polyvalent metal salts of organic acids, composite hydrous oxides, reducing substances, antibacterial agents,

deodorants, water-soluble polymers, water-insoluble polymers, water, organic fine particles, reducing agents, oxidizing agents, and inorganic salts.

[0075]

A content of the additional additive varies depending on the purpose and additional function. For example, the content of each type of additive is usually in a range of 0 parts by mass or more and 10 parts by mass or less, preferably 0.001 parts by mass or more and 5 parts by mass or less, and more preferably 0.002 parts by mass or more and 3 parts by mass or less, with respect to 100 parts by mass of the crosslinked polymer. One or more of the additives can be used.

[0076]

In this case, a sufficient effect and/or additional function due to addition of the additive can be obtained, and the absorption performance of the water absorbent can be maintained.

[0077]

2-7. Physical Properties of Water Absorbent

Centrifuge Retention Capacity (CRC) (NWSP 241.0.R2 (15))

CRC is generally an abbreviation for Centrifuge Retention Capacity and is a parameter referred to as fluid retention capacity without pressure.

[0078]

Specifically, the CRC means fluid retention capacity (unit: g/g) measured after 0.2 g of the water absorbent is put in a nonwoven fabric bag, then the bag is immersed in a large excess of a 0.9 mass% aqueous sodium chloride solution for 30 minutes to freely swell the water absorbent, and then water is removed using a centrifuge (250 G). The CRC can be measured, for example, by the method described in Examples.

[0079]

The CRC of the water absorbent of the present invention is 25 g/g or less, preferably 23 g/g or less, and more preferably 20 g/g or less.

[0080]

The CRC is 5 g/g or more, preferably 7 g/g or more, and more preferably 10 g/g or more. The CRC being equal to or more than the lower limit value is preferable from the viewpoint of maintaining the water absorption performance such as the water absorption speed of the water absorbent of the present invention. A value of the CRC can be controlled by adjusting the water absorption ability of the crosslinked polymer through changing the types and amounts of internal crosslinking agent, surface-crosslinking agent, and the like.

[0081]

Bulk Specific Gravity

A bulk specific gravity of the water absorbent of the present invention is a parameter representing the mass per unit volume. The bulk specific gravity is the mass (unit; [g/mL]) of the water absorbent when the water absorbent is packed in a 10-mL container by free falling.

[0082]

The bulk specific gravity is less than 0.3 g/ml, preferably 0.27 g/mL or less, more preferably 0.25 g/mL or less, still more preferably 0.20 g/mL or less, and yet still more preferably 0.17 g/mL or less. When the bulk specific gravity is equal to or less than the upper limit value, the water absorbent of the present invention has a structure in which the continuous pores are large and/or the number of the continuous pores is large as described above, and as a result, both the water absorption speed and the water separation percentage of the water absorbent are improved.

[0083]

The bulk specific gravity is preferably 0.05 g/mL or more, and more preferably 0.07 g/mL or more. The bulk specific gravity is preferably equal to or more than the lower limit value from the viewpoint of maintaining the water absorption performance of the water absorbent of the present invention, such as CRC.

[0084]

Water Absorption Speed (Vortex)

A water absorption speed of the water absorbent of the present invention is represented by, for example, a value (water absorption speed (Vortex): unit [second]) measured by a method generally called a Vortex method. A smaller value of the water absorption speed (Vortex) means a faster and more excellent water absorption speed. The value of the water absorption speed (Vortex) of the water absorbent of the present invention is preferably a small value, and specifically, is preferably 10 seconds or less, more preferably 7 seconds or less, still more preferably 5 seconds or less, and particularly preferably 2 seconds or less. The value of the water absorption speed (Vortex) can be measured, for example, by the method described in Examples.

[0085]

Free Swell Capacity (FSC) (NWSP 240.0.R2 (15))

A free swell capacity (FSC) of the water absorbent of the present invention is an abbreviation for Free Swell Capacity, and means a fluid retention capacity of a water absorbent in hanging without pressure. In the present specification, the FSC is measured in accordance with NWSP 240.0.R2 (15). A value of the FSC of the water absorbent can be controlled by changing the types and amounts of internal crosslinking agent, surface-crosslinking agent, and the like and adjusting the water absorption ability of the crosslinked polymer.

[0086]

The value of the FSC is preferably 35 g/g or more, more preferably 40 g/g or more, and still more preferably 50 g/g or more. The value of the FSC is preferably 150 g/g or less, more preferably 120 g/g or less, and still more preferably 100 g/g or less. When the value of the FSC is within the above range, the water absorption speed and the water separation percentage of the water absorbent of the present invention can be further improved.

[0087]

Water Separation Percentage

The water separation percentage of the water absorbent of the present invention is a parameter representing the ease of release of a liquid such as water when a certain pressure (centrifugal force) is applied to the water absorbent that is in a swollen state by absorbing the liquid. The water separation percentage is represented by the following Formula (1).

Water separation percentage [%] = {(FSC [g/g] - CRC [g/g])/FSC [g/g]} × 100 (1)

A high value of the water separation percentage means that the liquid absorbed by the swollen water absorbent is more easily released and that the water separation percentage is excellent. A value of the water separation percentage is preferably higher, and specifically, is preferably 40% or more, more preferably 50% or more, and still more preferably 60% or more. In addition, the value of the water separation percentage may be usually 95% or less.

[0088]

pH

A pH of the water absorbent of the present invention is controlled to fall within a range in weak acidity, and specifically, may be in a range from 4.5 to 6.5, and preferably in a range from 5.0 to 6.0. The pH can be controlled by adjusting the rate of neutralization in the monomer composition as a raw material to fall within the above-described range. The pH can be measured by the method described in Examples.

[0089]

Mass Average Particle Size (D50)

The water absorbent of the present invention is a porous body and may have a particulate shape. A mass average particle size (D50) of the water absorbent may be preferably 100 μm or more and 1000 μm or less, more preferably 300 μm or more and 800 μm or less, and still more preferably 400 μm or more and 700 μm or less. The mass average particle size (D50) corresponds to the mesh opening size of the standard sieve which 50 mass% of the whole particles pass in evaluating by the standard sieve having a certain mesh opening. The D50 can be measured, for example, by the method described in Examples.

[0090]

2-8. Production Method

The water absorbent of the present invention can be produced, for example, by the method for producing a water absorbent according to an embodiment of the present invention described later.

[0091]

2-9. Application of Water Absorbent

The water absorbent of the present invention is an organic porous body having continuous pores and a continuous skeleton formed of, as a main component, a crosslinked polymer, and therefore has a performance of absorbing and retaining a solution (liquid). Therefore, the water absorbent can be used in an absorbent body of a sanitary material or the like, and as described above, can be used in combination with a superabsorbent polymer or the like having excellent water absorption performance such as an existing water-absorbent resin.

Further, the water absorbent of the present invention is a particulate porous body, and therefore, can be mixed with a particulate superabsorbent polymer (water-absorbent resin) and conveniently used as a composition in an absorbent body or the like. Such a composite absorbent body including the water absorbent of the present invention and water-absorbent resin particles is also included in the present invention.

[0092]

3. Method for Producing Water Absorbent

The method for producing a water absorbent according to an embodiment of the present invention (hereinafter referred to as "production method of the present invention") is a method for producing a water absorbent, the water absorbent including an organic porous body containing continuous pores and a continuous skeleton including a crosslinked polymer, the crosslinked polymer containing a structural unit derived from (meth)acrylic acid (salt) as a main component, the method including:

an O/W emulsion preparation step of incorporating a first solvent into an aqueous monomer solution having a rate of neutralization of less than 70 mol% in the presence of a first surfactant in a way that a volume ratio of the first solvent to the aqueous monomer solution is 2.5 or more to obtain an O/W emulsion;

an O/W/O emulsion preparation step of dispersing the O/W emulsion in a second solvent to obtain an O/W/O emulsion; and

a polymerization step of polymerizing, in the O/W/O emulsion, a monomer contained in the aqueous monomer solution to prepare the organic porous body.

[0093]

As for the "crosslinked polymer", the "organic porous body", and the "water absorbent" in the production method of the present invention, the descriptions in the above section “2. Water Absorbent” are referred to.

[0094]

An issue to be solved by the present invention is to provide a water absorbent that can reduce skin roughness and the like of a user as compared with known water absorbents and is excellent in water absorption speed and water separation percentage. The present inventors have found that the water retention ability and the bulk specific gravity of a water absorbent produced by the production method of the present invention are controlled to fall within specific ranges, and that the water absorbent can solve the above problem. Further, the present inventors have found that the O/W emulsion having an O/W volume ratio of 2.5 or more can be prepared by making the rate of neutralization of the monomer smaller than the rate of neutralization of a known monomer, and that a water absorbent capable of solving the above problem can be produced. The rate of neutralization of the monomer corresponds to the rate of neutralization of the crosslinked polymer constituting the water absorbent to be produced.

[0095]

Here, with reference to FIG. 1, it will be described that the production method of the present invention can provide a water absorbent capable of solving the above-described problem. FIG. 1 is a schematic view illustrating an aspect of the O/W/O emulsion preparation step and the polymerization step of the production method of the present invention.

[0096]

The drawing at the left end of FIG. 1 illustrating an O/W emulsion prepared in the O/W emulsion preparation step of the production method of the present invention. In the O/W emulsion, as presented in the drawing at the left end of FIG. 1, a first solvent 1 is dispersed into an aqueous monomer solution 2, and the volume ratio of first solvent 1/aqueous monomer solution 2 (O/W volume ratio) is 2.5 or more.

[0097]

In the O/W/O emulsion preparation step of the production method of the present invention, as presented from the left to the center of FIG. 1, an O/W emulsion prepared in the O/W emulsion preparation step is added to a second solvent 3 and emulsified. Thus, an O/W/O emulsion in which an O/W emulsion 4 is dispersed in the second solvent 3 is prepared.

[0098]

Here, in the O/W emulsion 4, the first solvent is present in a state of being dispersed in the aqueous monomer solution. In addition, the O/W volume ratio in the O/W emulsion 4 is the same as the O/W volume ratio in the O/W emulsion prepared in the O/W emulsion preparation step.

[0099]

In the polymerization step of the production method of the present invention, as presented on the right side of FIG. 1, the monomers contained in the aqueous monomer solution in the O/W emulsion 4 are polymerized to form a crosslinked polymer. The crosslinked polymer forms a continuous skeleton constituting an organic porous body 5 prepared in the polymerization step. In addition, since the crosslinked polymer is not formed at the portion where the first solvent is present dispersed in the O/W emulsion 4, the portion where the first solvent is present becomes continuous pores constituting the organic porous body 5. Therefore, as presented in the drawing at the right end of FIG. 1, an organic porous body having a continuous skeleton formed of the crosslinked polymer and having a structure with continuous pores dispersed inside is prepared by the polymerization step. That is, in the production method of the present invention, a water absorbent including an organic porous body having the continuous pores and the continuous skeleton is produced. The organic porous body 5 in FIG. 1 may be a water absorbent.

[0100]

In the production method of the present invention, an aqueous monomer solution having a rate of neutralization of less than 70 mol% is used as a raw material. The rate of neutralization of the aqueous monomer solution is a proportion (unit: mol%) of the number of moles of neutralized monomers to the number of moles of all monomers (excluding the internal

crosslinking agent) in the aqueous monomer solution containing the monomer composition, and is a rate of neutralization of the crosslinked polymer obtained from the aqueous monomer solution. Therefore, the water absorbent produced by the production method of the present invention is controlled to be weakly acidic, and can reduce skin roughness and the like of a user of the water absorbent, for example, as compared with known water absorbents.

[0101]

The production method of the present invention is different from the production method described in Patent Document 1 and can produce a water absorbent including an organic porous body without hydrolysis. Therefore, the production method of the present invention does not require use of an excess of alkali, which is essential for hydrolysis. Therefore, according to the production method of the present invention, a water absorbent including an organic porous body can be produced while the rate of neutralization is arbitrarily adjusted to a small value of less than 70 mol%, and as a result, as described above, skin roughness and the like of a user of the water absorbent can be reduced.

[0102]

The continuous pores of the organic porous body 5 are formed at sites where the first solvent dispersed in the O/W emulsion 4 is present. In the production method of the present invention, the O/W volume ratio in the O/W emulsion 4 is 2.5 or more. Therefore, the proportion of the continuous pores in the organic porous body 5 is increased. In other words, the organic porous body 5 has a small portion occupied by the continuous skeleton and a large portion occupied by the continuous pores in the entire water absorbent.

[0103]

Here, as presented in the section “2. Water Absorbent”, when the portion occupied by the continuous pores is large, the liquid is more easily taken therein, and the liquid is more easily released when a centrifugal force (pressure) is applied. Therefore, the water absorbent containing the organic porous body 5 has both an improved water absorption speed and an improved water separation percentage.

[0104]

From the above, the production method of the present invention can produce a water absorbent that can reduce skin roughness and the like of a user of the water absorbent and is excellent in water absorption speed and water separation percentage as compared with known water absorbents.

[0105]

In the production method of the present invention, an O/W emulsion having an O/W volume ratio adjusted to 2.5 or more is prepared by using an aqueous monomer solution having a rate of neutralization of less than 70 mol% as a raw material. Then, the water absorbent containing the organic porous body is produced by polymerizing the monomer contained in the aqueous monomer solution in an O/W/O emulsion obtained by dispersing the O/W emulsion in a second solvent. In the production method of the present invention, the water absorbent including

the organic porous body is produced through controlling the particle size of the O/W/O emulsion. Thus, the production method of the present invention can produce a water absorbent having a predetermined particle size without pulverizing the organic porous body to be obtained. It is known that when the organic porous body is pulverized, a large amount of fine powder is produced as a by-product, and that productivity is lowered. Therefore, according to the production method of the present invention, it is possible to produce a water absorbent having a predetermined particle size while avoiding a decrease in productivity due to the by-production of a large amount of fine powder.

[0106]

Hereinafter, each step that constitutes the production method of the present invention will be described in detail.

[0107]

3-1. O/W Emulsion Preparation Step

The O/W emulsion preparation step of the production method of the present invention is a step of incorporating a first solvent into an aqueous monomer solution having a rate of neutralization of less than 70 mol% in the presence of a first surfactant in a way that a volume ratio of the first solvent to the aqueous monomer solution is 2.5 or more to obtaining an O/W emulsion.

[0108]

Aqueous Monomer Solution

The aqueous monomer solution is an aqueous solution containing a monomer as a raw material of the water absorbent to be produced, and optionally an internal crosslinking agent and the like. A concentration of the monomer in the aqueous monomer solution is usually preferably from 30 mass% to a saturation concentration, and more preferably from 35 to 45 mass%, with respect to a total mass of the aqueous monomer solution. The water used in the aqueous monomer solution is not particularly limited, and examples thereof include tap water, distilled water, and ion-exchanged water.

[0109]

The production method of the present invention may include an aqueous monomer solution preparation step of preparing the aqueous monomer solution before the O/W emulsion preparation step. This step is a step of dissolving the monomer and optionally an internal crosslinking agent and the like in water to prepare the aqueous monomer solution. This step may include adjusting the rate of neutralization of the aqueous monomer solution. As a method for adjusting the rate of neutralization, a known method can be adopted. Examples of the method can include a method of neutralizing an acid group of (meth)acrylic acid (salt) which is a main component of the monomer in the production method of the present invention, using a compound containing an alkali metal or the like. Examples of the alkali metal include lithium, sodium, and potassium. Among these alkali metals, sodium and potassium are preferable. One or more of the alkali metals can be used.

[0110]

The neutralization of the acid group can be performed by, for example, adding dropwise an aqueous solution of a compound containing an alkali metal such as sodium hydroxide and/or potassium hydroxide to the monomer or an aqueous solution containing the monomer, followed by mixing. A concentration of the compound containing an alkali metal in the aqueous solution is not particularly limited, but is usually about from 20 to 50 mass%.

[0111]

Monomer and Internal Crosslinking Agent

For the monomer and the internal crosslinking agent in the aqueous monomer solution, the descriptions in the sections “Monomer” and “Internal Crosslinking Agent” of “2-1. Crosslinked Polymer” of “2. Water Absorbent” can be referred. The "rate of neutralization of the crosslinked polymer" described in the section “Monomer” corresponds to the "rate of neutralization of the aqueous monomer solution", and the "content" corresponds to the "amount used" in the production method of the present invention.

[0112]

A preferable example of the aqueous monomer solution can be an aqueous monomer solution containing an internal crosslinking agent, wherein the internal crosslinking agent is at least one selected from a polyfunctional acrylate-based crosslinking agent, an acrylamide-based crosslinking agent, and a glycidyl ether-based crosslinking agent.

[0113]

Polymerization Initiator

When a polymerization initiator is used in the production method of the present invention, the polymerization initiator can be added to one or more of the aqueous monomer solution, the O/W emulsion, and the O/W/O emulsion at any time before the polymerization step is performed. The polymerization initiator is preferably added to the aqueous monomer solution in advance in order to uniformly disperse the polymerization initiator.

[0114]

As the polymerization initiator, a water-soluble radical polymerization initiator can be used. Examples of the water-soluble radical polymerization initiator include persulfates such as potassium persulfate, sodium persulfate, and ammonium persulfate; azo-based polymerization initiators such as 2,2′-azobis(2-amidinopropane) dihydrochloride and 2,2′-azobis(2-(2imidazoline-2-yl)propane) dihydrochloride; and hydrogen peroxide. The polymerization initiator that can be used in the production method of the present invention is not limited to the above-described polymerization initiators. The polymerization initiator is preferably an azo-based initiator and/or a persulfate. One or more of the polymerization initiators can be used.

[0115]

An amount of the polymerization initiator used is usually preferably from 0.05 to 10 mmol per mol of all monomers contained in the aqueous monomer solution.

[0116]

First Surfactant

The first surfactant used in the O/W emulsion preparation step is not particularly limited as long as the O/W emulsion can be prepared. Examples of the first surfactant can include nonionic surfactants such as polyoxyethylene-polyoxypropylene copolymers, polyoxyethylene alkyl ethers, polyoxypropylene alkyl ethers, hydrophobically modified polyether urethanes and hydrophobically modified polyester urethanes, polyoxyethylene glycerin monostearate, polyoxyethylene glycerin monoisostearate, rosin esters, and polyoxyethylene rosin esters; and anionic surfactants such as sodium lauryl sulfate and polyoxyethylene sodium lauryl sulfate. The first surfactant is preferably a polyoxyethylene-polyoxypropylene copolymer among the above-described compounds. One or more of the first surfactants can be used.

[0117]

The use of a polyoxyethylene-polyoxypropylene copolymer as the first surfactant is preferred because the copolymer can advantageously improve stability during polymerization in the polymerization step described below and form a large number of continuous pores. As the polyoxyethylene-polyoxypropylene copolymer, for example, a polyoxyethylene-polyoxypropylene-polyoxyethylene block copolymer can be used.

[0118]

A mass average molecular weight of the polyoxyethylene-polyoxypropylene-polyoxyethylene block copolymer is preferably 3000 or more, and more preferably 5000 or more, from the viewpoint of improving stability during polymerization in the polymerization step described later and forming a large number of continuous pores. The mass average molecular weight is preferably 100000 or less, and more preferably 30000 or less from the viewpoint of increasing water solubility and improving workability. From these viewpoints, the mass average molecular weight is preferably from 3000 to 100000, and more preferably from 5000 to 30000.

[0119]

A polyoxyethylene content of the polyoxyethylene-polyoxypropylene-polyoxyethylene block copolymer is preferably 40 mass% or more, and more preferably 45 mass% or more. In this case, when the monomer is polymerized in the O/W/O emulsion in the polymerization step described later, the O/W/O emulsion can be kept in a good emulsified state, and continuous pores can be easily formed inside the particles.

[0120]

The content is preferably 90 mass% or less, and more preferably 85 mass% or less, from the viewpoint of stabilizing the O/W emulsion dispersed in the O/W/O emulsion in the polymerization step described later. From these viewpoints, the content is preferably from 40 to 90 mass%, and more preferably from 45 to 85 mass%.

[0121]

The polyoxyethylene-polyoxypropylene-polyoxyethylene block copolymer is industrially easily available. Typical examples of the copolymer include "ADEKA PLURONIC" (trade name) series available from Asahi Denka Kogyo K. K., "PLURONIC" (trade name) series

available from BASF Co., Ltd., and "NEWPOL" (trade name) series available from Sanyo Chemical Industries, Ltd. These polyoxyethylene-polyoxypropylene-polyoxyethylene block copolymers may be used alone, or two or more thereof may be used in combination.

[0122]

An amount of the first surfactant used is preferably 0.1 parts by mass or more, and more preferably 0.5 parts by mass or more, with respect to 100 parts by mass of the aqueous monomer solution, from the viewpoint of facilitating dispersion of the first solvent in the aqueous monomer solution. In addition, even if the first surfactant is added in an excessive amount, there is a tendency that a commensurate effect cannot be obtained, and that such addition is rather uneconomical. Thus, the amount of the first surfactant used is preferably 15 parts by mass or less, and more preferably 10 parts by mass or less, with respect to 100 parts by mass of the aqueous monomer solution. From these viewpoints, the amount of the first surfactant used is preferably from 0.1 to 15 parts by mass, and more preferably from 0.5 to 10 parts by mass, with respect to 100 parts by mass of the aqueous monomer solution. The material to which the first surfactant is to be added and the addition timing of the first surfactant are not particularly limited, and the first surfactant needs only to be used at the time of preparing the O/W emulsion.

[0123]

First Solvent

The first solvent used in the O/W emulsion preparation step is not particularly limited as long as it is a hydrophobic organic solvent and can be dispersed in the aqueous monomer solution to obtain an O/W emulsion. The expression that "the first solvent is dispersed in the aqueous monomer solution" means that the first solvent is incorporated in the aqueous monomer solution.

[0124]

The first solvent is preferably a hydrocarbon-based organic solvent, such as one or more solvents selected from the group consisting of n-pentane, n-hexane, n-heptane, n-octane, cyclohexane, and methylcyclohexane. Among these, one or more solvents selected from the group consisting of n-hexane, n-heptane, and cyclohexane are more preferable because they are industrially easily available, have stable quality, and are relatively inexpensive.

[0125]

Properties of Aqueous Monomer Solution and O/W Emulsion

In the production method of the present invention, the O/W volume ratio in the O/W emulsion preparation step is 2.5 or more. The O/W volume ratio is a ratio of the volume (mL) of the first solvent to the volume (mL) of the aqueous monomer solution in the O/W emulsion.

[0126]

As described above, due to the O/W volume ratio being 2.5 or more, both the water absorption speed and the water separation percentage of the water absorbent produced by the production method of the present invention can be improved. The O/W volume ratio can be controlled by, for example, adjusting the amount of the first solvent used in the O/W emulsion preparation step.

[0127]

The O/W volume ratio is preferably 2.5 or more, more preferably 2.8 or more, still more preferably 3.0 or more, yet still more preferably 3.2 or more, and even yet still more preferably 5.0 or more from the viewpoint of improving both the water absorption speed and the water separation percentage of the water absorbent. In addition, when the O/W volume ratio is a specific value or less, emulsification is stabilized, the first solvent can be sufficiently incorporated in the aqueous monomer solution, and the O/W emulsion can be favorably prepared. From this viewpoint, the O/W volume ratio is preferably 15.0 or less, and more preferably 10.0 or less.

[0128]

A viscosity of the aqueous monomer solution at 25°C is preferably 500 mPa·s or more, and more preferably 1000 mPa·s or more, from the viewpoint of enhancing porosity of the obtained particles by stabilizing the O/W emulsion.

[0129]

The viscosity of the aqueous monomer solution can be adjusted using, for example, a polymer thickener.

[0130]

As the polymer thickener, for example, hydroxyethyl cellulose, carboxymethyl cellulose, guar gum, gum arabic, glucomannan, dextrin, polyvinyl alcohol, polyethylene oxide, and partially neutralized polyacrylic acid are preferably used. It is because that these polymer thickeners can impart a relatively high viscosity to the aqueous monomer solution even when the amount thereof used is small. One or more of the polymer thickeners can be used.

[0131]

Conditions for the O/W Emulsion Preparation Step

A method for preparing the O/W emulsion in the O/W emulsion preparation step is not particularly limited. Examples of the method can include a method in which the first surfactant is mixed with the aqueous monomer solution, and the first solvent is gradually added to the obtained mixture while stirring the mixture.

[0132]

A liquid temperature of the aqueous monomer solution in preparation of the O/W emulsion is preferably 30°C or lower, and more preferably from 15 to 25°C, from the viewpoint of stability of the O/W emulsion.

[0133]

In the preparation of the O/W emulsion, a stirring device or the like may be used. The stirring device is not particularly limited, and may be, for example, a device capable of fine emulsification such as a homomixer, or may be a general stirring blade such as a paddle type, a propeller type, or a screw type. In any of the stirring devices, the number and size of pores in the obtained particles can be appropriately adjusted by adjusting a stirring speed or the like.

[0134]

3-2. O/W/O Emulsion Preparation Step

The O/W/O emulsion preparation step of the production method of the present invention is a step of dispersing the O/W emulsion prepared in the O/W emulsion preparation step in a second solvent to obtain an O/W/O emulsion. The second solvent preferably contains the second surfactant from the viewpoint of favorably obtaining an O/W/O emulsion.

[0135]

Second Solvent

The second solvent used in the O/W/O emulsion preparation step is a dispersion medium of the O/W emulsion. The second solvent is not particularly limited as long as it is a hydrophobic organic solvent and can disperse the O/W emulsion to obtain an O/W/O emulsion. The second solvent is preferably a hydrocarbon-based organic solvent, such as one or more solvents selected from the group consisting of n-pentane, n-hexane, n-heptane, n-octane, cyclohexane, and methylcyclohexane. Among these, one or more solvents selected from the group consisting of n-hexane, n-heptane, and cyclohexane are more preferable because they are industrially easily available, have stable quality, and are relatively inexpensive.

[0136]

The first solvent and the second solvent may be of the same type or different types. The first solvent and the second solvent are preferably the same type from the viewpoint that the solvent recovered in a drying step or the like described below is easily reused.

[0137]

Second Surfactant

Examples of the second surfactant include sucrose fatty acid esters, (poly)glycerin fatty acid esters, sorbitan fatty acid esters, polyoxyethylene sorbitan fatty acid esters, polyoxyethylene glycerin fatty acid esters, sorbitol fatty acid esters, polyoxyethylene sorbitol fatty acid esters, polyoxyethylene alkyl ethers, polyoxyethylene alkyl phenyl ethers, polyoxyethylene castor oil, polyoxyethylene hydrogenated castor oil, alkylallyl formaldehyde condensed polyoxyethylene ethers, polyoxyethylene polyoxypropylene block copolymers, polyoxyethylene polyoxypropyl alkyl ethers, polyethylene glycol fatty acid esters, alkyl glucosides, N-alkyl gluconamides, polyoxyethylene fatty acid amides, polyoxyethylene alkylamine, phosphoric acid esters of polyoxyethylene alkyl ethers, and phosphoric acid esters of polyoxyethylene alkyl allyl ethers. These surfactants may each be used alone, or two or more thereof may be mixed and used.

[0138]

The second surfactant is preferably at least one selected from the group consisting of sucrose fatty acid esters, sorbitan fatty acid esters, sorbitol fatty acid esters, and polyglycerin fatty acid esters, and sucrose fatty acid esters are more preferable because of their excellent safety.

[0139]

In the present specification, the "(poly)" means both the case where there is a prefix "poly" and the case where there is no prefix "poly".

[0140]

An amount of the second surfactant used is preferably 0.5 parts by mass or more, and more preferably 1 part by mass or more, with respect to 100 parts by mass of the aqueous monomer solution, from the viewpoint of ensuring stability during polymerization in the polymerization step described later. The amount of the second surfactant used is preferably 10 parts by mass or less, and more preferably 5 parts by mass or less, with respect to 100 parts by mass of the aqueous monomer solution. This is because even if the second surfactant is added in an excessive amount, there is a tendency that a commensurate effect cannot be obtained, and that such addition is rather uneconomical. From these viewpoints, the amount of the second surfactant is preferably from 0.5 to 10 parts by mass, and more preferably from 1 to 5 part(s) by mass, with respect to 100 parts by mass of the aqueous monomer solution.

[0141]

Conditions for the O/W/O Emulsion Preparation Step

A method for preparing the O/W/O emulsion in the O/W/O emulsion preparation step is not particularly limited. Examples of the method include a method in which the O/W emulsion is fed into the second solvent with a liquid feeder such as a tube pump and added while stirring. The device used in stirring is not particularly limited, and for example, a paddle type stirring blade used in stirring in a flask can be used.

[0142]

3-3. Polymerization Step

The polymerization step of the production method of the present invention is a step of polymerizing, in the O/W/O emulsion prepared in the O/W/O emulsion preparation step, the monomer contained in the aqueous monomer solution to prepare an organic porous body.

[0143]

A reaction temperature at which a polymerization reaction of the monomer is performed in the polymerization step varies depending on the type of the polymerization initiator to be used, and therefore cannot be determined unconditionally. The reaction temperature is preferably from 40 to 100°C, and more preferably from 50 to 80°C, from the viewpoint of allowing the polymerization reaction to proceed rapidly and shortening the polymerization time to thereby enhance the economic efficiency, while performing the polymerization reaction without boiling the first or second organic solvent.

[0144]

When the reaction temperature is 60°C or higher, a polymer dispersion stabilizer is preferably used from the viewpoint of maintaining stability of the O/W/O emulsion during the polymerization reaction of the monomer. Suitable examples of the polymer dispersion stabilizer include maleic anhydride-modified polyethylene, maleic anhydride-modified polypropylene, maleic anhydride-modified ethylene-propylene copolymer, maleic anhydride-modified ethylene-propylene-diene terpolymer (EPDM), maleic anhydride-modified polybutadiene, maleic anhydride-ethylene copolymer, maleic anhydride-propylene copolymer, maleic anhydride-

ethylene-propylene copolymer, maleic anhydride-butadiene copolymer, polyethylene, polypropylene, ethylene-propylene copolymer, oxidized polyethylene, oxidized polypropylene, oxidized ethylene-propylene copolymer, ethylene-acrylic acid copolymer, ethyl cellulose, and hydroxyethyl cellulose.

[0145]

Among them, maleic anhydride-modified polyethylene, maleic anhydride-modified polypropylene, maleic anhydride-modified ethylene-propylene copolymer, maleic anhydride-ethylene copolymer, maleic anhydride-propylene copolymer, maleic anhydride-ethylene-propylene copolymer, polyethylene, polypropylene, ethylene-propylene copolymer, oxidized polyethylene, oxidized polypropylene, oxidized ethylene-propylene copolymer, and the like are exemplified as more suitable polymer dispersion stabilizers, from the viewpoint of dispersion stability of the aqueous monomer solution. The polymer dispersion stabilizer may be one type or a mixture of two or more types of polymer dispersion stabilizers. The polymer dispersion stabilizer and the second surfactant may be used in combination.

[0146]

An amount of the polymer dispersion stabilizer used is preferably 0.5 parts by mass or more, and more preferably 1 part by mass or more, with respect to 100 parts by mass of the aqueous monomer solution, from the viewpoint of sufficiently stabilizing the O/W/O emulsion. The amount of the polymer dispersion stabilizer used is preferably 10 parts by mass or less, and more preferably 5 parts by mass or less, with respect to 100 parts by mass of the aqueous monomer solution. When the polymer dispersion stabilizer is added in an excessive amount, a commensurate effect cannot be obtained, and such addition may be rather uneconomical.

[0147]

A reaction time of the polymerization reaction is not particularly limited, and is usually about from 0.5 to 3 hours.

[0148]

3-4. Post-Crosslinking Step

The organic porous body is usually obtained in the form of hydrogel particles by the polymerization step. From the viewpoint of increasing the water absorption speed and gel strength of the organic porous body and the water absorbent containing the organic porous body, the production method of the present invention may include a post-crosslinking step of subjecting the organic porous body obtained by the polymerization step to a post-crosslinking reaction. The post-crosslinking step causes the crosslinked polymer constituting the organic porous body to be post-crosslinked, that is, surface-crosslinked. The post-crosslinking step provides an organic porous body formed from the continuous pores and the crosslinked polymer which has been surface-crosslinked. Hereinafter, the organic porous body obtained by the post-crosslinking step is also referred to as "organic porous body after surface-crosslinking".

[0149]

Post-Crosslinking Agent

As the post-crosslinking agent, a crosslinking agent capable of reacting with a reactive group in the crosslinked polymer can be used.

[0150]

Specific examples of the post-crosslinking agent include polyols such as ethylene glycol, propylene glycol, trimethylolpropane, glycerin, (poly)oxyethylene glycol, polyoxypropylene glycol, and polyglycerin; ether compounds having two or more glycidyl groups such as (poly)ethylene glycol diglycidyl ether, (poly)propylene glycol diglycidyl ether, and (poly)glycerin triglycidyl ether; and compounds having two or more reactive functional groups such as haloepoxy compounds such as epichlorohydrin, epibromohydrin, and α-methylepichlorohydrin. These post-crosslinking agents can be used alone, or two or more thereof can be mixed and used. Among the post-crosslinking agents, preference is given to (poly)ethylene glycol diglycidyl ethers.

[0151]

An amount of the post-crosslinking agent used varies depending on the moisture content of the crosslinked polymer, the treatment temperature, and the like, and therefore cannot be determined unconditionally. The moisture content of the crosslinked polymer is the same as the moisture content of the organic porous body.

[0152]

An addition timing of the post-crosslinking agent may be any timing after completion of the polymerization reaction. The addition timing is, for example, preferably a time point when the moisture content of the crosslinked polymer is 10 mass% or more, and more preferably a time point when the moisture content of the crosslinked polymer is 20 mass% or more, from the viewpoint of allowing the post-crosslinking reaction to sufficiently proceed and increasing the water absorption speed of the water absorbent. In addition, from the viewpoint of preventing the water retention ability of the water absorbent from becoming too low, the addition timing is preferably a time point when the moisture content of the crosslinked polymer is 80 mass% or less, and more preferably a time point when the moisture content of the crosslinked polymer is 65 mass% or less. From these viewpoints, the addition timing of the post-crosslinking agent is preferably a time point when the moisture content of the crosslinked polymer is from 10 to 80 mass%, and more preferably a time point when the moisture content of the crosslinked polymer is from 20 to 65 mass%.

[0153]

Dehydration Treatment

The post-crosslinking step may include a dehydration treatment for removing water from the crosslinked polymer to adjust the moisture content thereof before adding the post-crosslinking agent to the crosslinked polymer. As a method of dehydration, a known method can be employed. Examples of the method can include a method of distilling off water and a hydrophobic organic solvent by an azeotropic distillation column.

[0154]

An amount of moisture in the hydrogel and a solid content in the hydrogel, that is, a solid content of the crosslinked polymer can be calculated from amounts of raw material compounds such as monomers charged in the polymerization reaction and an amount of moisture removed in the dehydration treatment and drying step described below.

[0155]

Method, Conditions, and the Like of Post-Crosslinking

The post-crosslinking reaction in the post-crosslinking step can be performed by, for example, adding a solution of a post-crosslinking agent to a hydrogel adjusted to a predetermined moisture content, which is obtained by subjecting the hydrogel after completion of the polymerization reaction to the dehydration treatment.

[0156]

The solution of the post-crosslinking agent is, for example, a solution with the post-crosslinking agent dissolved in water or an alcohol and from 0.5 to 50 mass% concentration of the post-crosslinking agent. When the post-crosslinking reaction is performed, the solution of the post-crosslinking agent may be dried immediately after the addition, and it is more preferable to maintain an internal temperature at from 50 to 90 °C for from 0.5 to 6 hours to promote the post-crosslinking reaction. The internal temperature means a temperature of the hydrogel after the solution of the post-crosslinking agent is added, that is, a temperature of a mixture of the solution of the post-crosslinking agent and the hydrogel.

[0157]

3-5. Drying Step

The production method of the present invention may include a drying step of removing water and the hydrophobic organic solvent from the organic porous body obtained by the polymerization step or the surface-crosslinked organic porous body obtained by the post-crosslinking step.

[0158]

As a method for removing the water and the hydrophobic organic solvent, a known method can be adopted. Examples of the method can include distilling off water and the hydrophobic organic solvent by an azeotropic distillation column, filtration, and drying under reduced pressure. As the method, only one method may be adopted, or a combination of two or more methods may be adopted. By carrying out the drying step, a water absorbent having a low moisture content and dried can be favorably produced.

[0159]

3-6. Chelating Agent Mixing Step

The production method of the present invention may include a chelating agent mixing step of mixing the aqueous monomer solution or the organic porous body with a chelating agent. The organic porous body may be an organic porous body obtained in the polymerization step, or may be a surface-crosslinked organic porous body obtained after the post-crosslinking step.

[0160]

The type and amount of the chelating agent used in the chelating agent mixing step are not particularly limited, and the descriptions regarding the type and content of the chelating agent presented in the section “2-4. Chelating Agent” of “2. Water Absorbent” above can be referred to.

[0161]

3-7. Inorganic Fine Particle Mixing Step

The production method of the present invention may include an inorganic fine particle mixing step of mixing the organic porous body and inorganic fine particles. The organic porous body may be an organic porous body obtained in the polymerization step, or may be a surface-crosslinked organic porous body obtained after the post-crosslinking step.

[0162]

The type and amount of the inorganic fine particles used in the inorganic fine particle addition step are not particularly limited, and the descriptions regarding the type and content of the inorganic fine particles presented in the section “2-5. Inorganic Fine Particle of “2. Water Absorbent” can be referred to.

[0163]

3-8. Step of Mixing Additional Additive

The production method of the present invention may include a step of mixing the organic porous body with an additional additive. The organic porous body may be an organic porous body obtained in the polymerization step, or may be a surface-crosslinked organic porous body obtained after the post-crosslinking step.

[0164]

The type and amount of the additional additive used in this step are not particularly limited, and the descriptions regarding the type and content of the additional additive presented in the section “2-6. Additional Additive” of “2. Water absorbent” above can be referred to.

[0165]

3-9. Recovery Step

The production method of the present invention may include a recovery step of separating and recovering fine powder from the produced organic porous body. The fine powder which has been separated may be added to the steps such as the O/W emulsion preparation step and the O/W/O emulsion preparation step and reused.

[0166]

An embodiment of the present invention may include inventions [1] to [13] below.

[0167]

[1] A water absorbent, including an organic porous body containing continuous pores and a continuous skeleton, the continuous skeleton including a crosslinked polymer, the crosslinked polymer containing a structural unit derived from (meth)acrylic acid (salt) as a main component, wherein

a centrifuge retention capacity (CRC) is from 5 to 25 g/g;

a bulk specific gravity is less than 0.3 g/ml; and

a rate of neutralization of the crosslinked polymer is less than 70 mol%.

[0168]

[2] The water absorbent according to [1], wherein a water absorption speed (Vortex) using physiological saline is 10 seconds or less.

[0169]

[3] The water absorbent according to [1] or [2], wherein a free swell capacity (FSC) is 35 g/g or more.

[0170]

[4] The water absorbent according to any one of [1] to [3], wherein a water separation percentage represented by the following Formula (1) is 40% or more:

[0171]

water separation percentage [%] = {(FSC [g/g] - CRC [g/g])/FSC [g/g]} × 100 ·· (1)

[5] The water absorbent according to any one of [1] to [4], wherein the water absorbent contains a chelating agent.

[0172]

[6] The water absorbent according to any one of [1] to [5], wherein the water absorbent contains inorganic fine particles.

[0173]

[7] A method for producing a water absorbent, the water absorbent including an organic porous body containing continuous pores and a continuous skeleton, the continuous skeleton including a crosslinked polymer, the crosslinked polymer containing a structural unit derived from (meth)acrylic acid (salt) as a main component, the method including:

an O/W emulsion preparation step of incorporating a first solvent, with a first surfactant, into an aqueous monomer solution having a rate of neutralization of less than 70 mol% in a way that a volume ratio of the first solvent to the aqueous monomer solution is 2.5 or more to obtain an O/W emulsion;

an O/W/O emulsion preparation step of dispersing the O/W emulsion in a second solvent to obtain an O/W/O emulsion; and

a polymerization step of polymerizing, in the O/W/O emulsion, a monomer contained in the aqueous monomer solution to prepare an organic porous body.

[0174]

[8] The method for producing a water absorbent according to [7], wherein

the aqueous monomer solution contains a polymerization initiator, and

the polymerization initiator is an azo-based initiator and/or a persulfate.

[0175]

[9] The method for producing a water absorbent according to [7] or [8], wherein

the aqueous monomer solution contains an internal crosslinking agent, and

the internal crosslinking agent is at least one selected from the group consisting of a polyfunctional acrylate-based crosslinking agent, a polyfunctional acrylamide-based crosslinking agent, and a polyfunctional glycidyl ether-based crosslinking agent.

[0176]

[10] The method for producing a water absorbent according to any one of [7] to [9], wherein the first surfactant includes a polyoxyethylene-polyoxypropylene-polyoxyethylene block copolymer.

[0177]

[11] The method for producing a water absorbent according to any one of [7] to [10], wherein the second solvent contains a second surfactant.

[0178]

[12] The method for producing a water absorbent according to [11], wherein the second surfactant includes at least one selected from the group consisting of sucrose fatty acid esters, sorbitan fatty acid esters, sorbitol fatty acid esters, and polyglycerin fatty acid esters.

[0179]

[13] The method for producing a water absorbent according to any one of [7] to [12], wherein the first solvent and the second solvent are of the same type.

[0180]

[14] A composite absorbent body, including the water absorbent according to any one of [1] to [6] and water-absorbent resin particles.

[0181]

The present invention is not limited to each embodiment described above, and it may be changed in various ways within the scope of the claims. Thus, an embodiment achieved by appropriately combining technical means described herein with different embodiments will be included in the technical scope of the present invention.

Examples

[0182]

Measurement and Calculation of Physical Property Values

Physical property values of water absorbents 1 to 6 and a comparative water absorbent 1 produced in Examples 1 to 6 and Comparative Example 2, respectively, were measured and evaluated by the methods presented below.

[0183]

Centrifuge Retention Capacity (CRC)

The CRC of the water absorbent was measured in accordance with NWSP 241.0.R2 (15). Specifically, 0.2 g of the water absorbent was put in a nonwoven fabric bag, and then the bag was immersed in a large excess of a 0.9 mass% aqueous sodium chloride solution for 30 minutes to freely swell the water absorbent. Thereafter, the water absorbent was dehydrated for 3 minutes using a centrifuge (250 G), and then the CRC (unit: g/g) was measured.

[0184]

Bulk Specific Gravity

The water absorbent was added to a cylindrical plastic container having a volume of 10 mL (inside diameter: 2.5 cm) until the water absorbent was heaped up and spilled out of the container, and then the water absorbent was leveled off on an upper surface of the container using a flat leveling rod. At this time, in order to prevent the water absorbent from being densely packed in the container, the operation was performed so as not to apply vibration to the container as much as possible. Thereafter, the weight of the water absorbent packed in the container was calculated from a change (difference) in the weight of the container before and after the water absorbent was packed in the container. The weight was divided by the volume (10 mL) of the container to determine the bulk specific gravity (unit: g/mL) of the water absorbent.

[0185]

Water Absorption Speed (Vortex)

0.02 parts by weight of Food Blue No. 1, which is a food additive, was added to 1000 parts by weight of 0.90 wt.% aqueous sodium chloride solution (physiological saline), and the liquid temperature was adjusted to 30°C. Next, 50 ml of the physiological saline was weighed into a 100-ml beaker, and 2.0 g of the water absorbent was added to the beaker with stirring at 600 rpm using a cylindrical stirring bar having a length of 40 mm and a thickness (diameter of a cross section perpendicular to the length direction of the cylinder) of 8 mm, and the Vortex (water absorption speed: seconds) of the water absorbent was measured.

[0186]

The end point of the measurement of the water absorption speed was measured in accordance with the standard described in JIS K 7224-1996 "Testing Method for Water Absorption Speed of Super Absorbent Polymers", and the time (Vortex: seconds) required for the sample to absorb the physiological saline and cover the stirrer chip with the test solution was measured as the water absorption speed (seconds).

[0187]

Free Swell Capacity (FSC)

The FSC of the water absorbent was measured in accordance with NWSP 240.0.R2 (15). Specifically, 0.2 g of the water absorbent was put in a nonwoven fabric bag, and then the bag was immersed in a large excess of a 0.90 mass% aqueous sodium chloride solution for 30 minutes to freely swell the water absorbent. Thereafter, the bag was pulled up and hung for 10 minutes to remove water, and then the fluid retention capacity (unit: g/g) was determined.

[0188]

Water Separation Percentage

The water separation percentage of the water absorbent was calculated based on the following Formula (1) using the CRC and FSC of the water absorbent.

Water separation percentage [%] = {(FSC [g/g] - CRC [g/g])/FSC [g/g]} × 100 (1)

pH

The pH of the water absorbent was measured in accordance with NWSP 200.0.R2 (15). Specifically, 100 ml of a 0.90 mass% aqueous sodium chloride solution at 23°C was weighed and put in a beaker. Next, while the aqueous sodium chloride solution in the beaker was stirred at 150 rpm with a cylindrical stirring bar having a length of 40 mm and a thickness (diameter of a cross section perpendicular to the length direction of the cylinder) of 8 mm, 0.5 g of the water absorbent was added into the aqueous sodium chloride solution. Subsequently, the aqueous sodium chloride solution was stirred for 10 minutes to swell the water absorbent. Thereafter, a pH electrode was inserted into the aqueous sodium chloride solution, and the pH at the time when the value was stabilized was read.

[0189]

Mass Average Particle Size (D50)

The "mass average particle size (D50)" of the water absorbent was measured in accordance with "(3) Mass-Average Particle Size (D50) and Logarithmic Standard Deviation (σζ) of Particle Size Distribution" described in columns 27 and 28 of US 7638570.

[0190]

Fine Powder Increase Amount (Damage Test)

The fine powder increase amount of the water absorbent was measured as follows.

[0191]

In a glass container (mayonnaise bottle available from Nihon Yamamura Glass Co., Ltd., diameter: 6 cm, height: 11 cm) having a volume of 242 ml (inner lid-attached, volume: 225 ml), 10 g of glass beads (soda-lime glass beads for precision fractional distillation packing) having a diameter of 6 mm and 3 g of the water absorbent were put. After covering the container with a resinous inner lid (made of polyethylene) and an outer lid (made of polypropylene), the container was attached to a paint shaker (Toyo Seiki Seisaku-sho, Ltd., Product No. 488) and shaken at 800 cycle/min (CPM) for 10 minutes to mechanically damage the water absorbent.

[0192]

Next, the samples before and after the damage test were sieved with a JIS standard sieve having a mesh size of 150 μm, and a ratio of the fine powder that passed through the sieve to the test sample was defined as the amount of fine powder (wt.%), and an increase amount before and after the test (amount of fine powder after test - amount of fine powder before test) was calculated.

[0193]

Example 1

(1) Preparation of O/W Emulsion

A 1000-mL four-necked separable flask (1) (hereinafter referred to as "flask (1)") equipped with a stirrer, a dropping funnel, a fluorine resin tube for nitrogen gas blowing, and a thermometer was prepared. The flask (1) was charged with 16.85 g of acrylic acid, 39.63 g of a 37 mass% aqueous sodium acrylate solution, and 2.00 g of methylene bisacrylamide. The rate of neutralization of the acrylic acid (salt) was 40 mol%. Subsequently, 0.64 g of hydroxyethyl cellulose was added to the flask (1), followed by stirring.

[0194]

An aqueous solution A was prepared in which 2.27 g of a polyoxyethylene-polyoxypropylene copolymer [trade name: ADEKA PLURONIC F-108, available from Asahi Denka Kogyo K.K., mass average molecular weight: 15500] was dissolved in 21.61 g of ion-exchanged water. Further, an aqueous solution B was prepared in which 0.05 g of 2,2'-azobis(2-methylpropionamidine) dihydrochloride was dissolved in 2.59 g of ion-exchanged water.

[0195]

The aqueous solution A and the aqueous solution B were added to the flask (1), and mixed and dissolved to prepare an aqueous monomer solution. Next, while the aqueous monomer solution was stirred at a rotation speed of 600 rpm, 433.3 g (646 mL) of n-heptane was added dropwise to the aqueous monomer solution at a flow rate of 11 mL/min. As a result, an O/W emulsion in which the n-heptane was dispersed in the aqueous monomer solution was obtained. The O/W volume ratio of the O/W emulsion was 88/12 = 7.3.

[0196]

(2) Preparation of O/W/O Emulsion

A 2000-mL four-necked separable flask (2) (hereinafter referred to as "flask (2)") equipped with a stirrer, a reflux condenser, a fluorine resin tube for nitrogen gas blowing, and a thermometer was prepared, and 670 g of n-heptane (1000 mL) was poured into the flask (2). Subsequently, 3.11 g of a sucrose fatty acid ester [available from MITSUBISHI-CHEMICAL FOODS CORPORATION, trade name: S-370] and 3.11 g of maleic anhydride-modified polyethylene [available from Mitsui Chemicals, Inc., trade name: HI-WAX1105A] were added to the flask (2).

[0197]

Next, while the mixture was stirred with nitrogen gas blown into the flask (2) at a flow rate of 100 mL/min, the flask (2) was immersed in a hot water bath at 80°C, and the mixture was stirred until the inside of the flask became uniform. Thereafter, the flask (2) was allowed to cool to 60°C while stirring the mixture at a rotation speed of the stirrer of 700 rpm. Thereafter, the O/W emulsion prepared in (1) above was added dropwise into the flask (2) at a flow rate of 60 mL/min to prepare an O/W/O emulsion.

[0198]

(3) Polymerization and Drying

The flask (2) containing the O/W/O emulsion prepared in (2) above was immersed in a hot water bath at 70°C to raise the temperature of the O/W/O emulsion, and a polymerization reaction was carried out for 1.5 hours while stirring the emulsion at a rotation speed of the stirrer of 700 rpm. Subsequently, the O/W/O emulsion after the polymerization reaction was subjected to a dehydration treatment by azeotropic distillation under a condition of 100°C to obtain a slurry.

[0199]

The solvent was removed from the slurry by a filtration using a sieve having a mesh size of 125 μm to collect filtered residues. The filtered residues were dried under reduced pressure at

60°C for 2 hours to produce 35 g of an organic porous body having a mass average particle size of 554 μm. The organic porous body was used as a water absorbent 1.

[0200]

Example 2

An organic porous body was produced in the same manner as in Example 1 except for the following changes (i) and (ii). The rate of neutralization of the acrylic acid (salt) used in Example 2 was 50 mol%.

[0201]

(i) The amount of the acrylic acid used was changed to 13.67 g.

[0202]

(ii) The amount of the 37 mass% aqueous sodium acrylate solution used was changed to 48.23 g.

[0203]

The produced organic porous body had a mass average particle size of 524 μm and a mass of 34 g. The organic porous body was used as a water absorbent 2.

[0204]

Example 3

An organic porous body was produced in the same manner as in Example 2 except for the following changes (iii) and (iv). The rate of neutralization of the acrylic acid (salt) used in Example 3 was 50 mol% as in Example 2.

[0205]

(iii) The 2.00 g of methylene bisacrylamide was changed to 6.59 g of polyethylene glycol diacrylate (n-9).

[0206]

(iv) The aqueous solution of 2,2'-azobis(2-methylpropionamidine) dihydrochloride was changed to an aqueous solution obtained by dissolving 0.05 g of sodium persulfate in 0.4 g of ion-exchanged water.

[0207]

The produced organic porous body had a mass average particle size of 542 μm and a mass of 34 g. The organic porous body was used as a water absorbent 3.

[0208]

Example 4

An organic porous body was produced in the same manner as in Example 2 except for the following changes (v) and (vi). The rate of neutralization of the acrylic acid (salt) used in Example 4 was 50 mol% as in Example 2. In addition, the O/W volume ratio of the O/W emulsion of Example 4 was 76/24 = 3.2.

[0209]

(v) The amount of the n-heptane used in the preparation of the O/W emulsion was changed to 216.7 g (323 mL).

[0210]

(vi) The rotation speed of the stirrer during preparation of the O/W/O emulsion was changed to 350 rpm.

[0211]

The produced organic porous body had a mass average particle size of 478 μm and a mass of 33 g. The organic porous body was used as a water absorbent 4.

[0212]

Example 5

An organic porous body was produced in the same manner as in Example 1 except for the following changes (vii) and (viii). The rate of neutralization of the acrylic acid (salt) used in Example 5 was 60 mol%.

[0213]

(vii) The amount of the acrylic acid used was changed to 10.66 g.

[0214]

(viii) The amount of the 37 mass% aqueous sodium acrylate solution used was changed to 56.36 g.

[0215]

The produced organic porous body had a mass average particle size of 488 μm and a mass of 35 g. The organic porous body was used as a water absorbent 5.

[0216]

Example 6

The organic porous body obtained in Example 2 was subjected to the following steps (ix) and (x) to produce an organic porous body.

(ix) With 100 parts by mass of the organic porous body obtained in Example 2, 1.0 parts by mass of pure water and 0.01 parts by mass of diethylenetriaminepentaacetic acid trisodium (DTPA·3Na) were uniformly mixed. Thereafter, the mixture was subjected to a heat treatment at 60°C for 45 minutes under a windless condition, and then crushed so that the mixture passed through a JIS standard sieve having a mesh size of 850 μm.

[0217]

(x) With 100 parts by mass of the organic porous body obtained through the step (ix), 1.0 parts by mass of silica (product name: AEROSIL 200CF, available from Nippon Aerosil Co., Ltd.) was mixed. The mixing was carried out by putting 6 g of the organic porous body together with the silica in a mayonnaise bottle available from Nihon Yamamura Glass Co., Ltd., which was used in the damage test, fastening an inner lid and an outer lid, and then applying vibration (at room temperatures for 1 minute) of a paint shaker (available from Toyo Seiki Seisaku-sho, Ltd.).

[0218]

The produced organic porous body had a mass average particle size of 520 μm. The organic porous body was used as a water absorbent 6.

[0219]

Comparative Example 1

The same method as in Example 1 was carried out except for the following changes (xi) and (xii). The rate of neutralization of the acrylic acid (salt) used in Comparative Example 1 was 75 mol%.

[0220]

(xi) The amount of the acrylic acid used was changed to 6.41 g.

[0221]

(xii) The amount of the 37 mass% aqueous sodium acrylate solution used was changed to 67.85 g.

[0222]

As a result, the aqueous monomer solution and n-heptane were not emulsified during the preparation of the O/W emulsion, and phase separation occurred, and therefore an organic porous body could not be produced.

[0223]

Comparative Example 2

An organic porous body was produced by the same method as in Example 1 of Patent Document 1, specifically, by the following method.

[0224]

Mixed and uniformly dissolved were 9.2 g of t-butyl methacrylate, 0.28 g of divinylbenzene, 1.0 g of sorbitan monooleate, and 0.4 g of 2,2′-azobis(isobutyronitrile) to obtain a mixture.

[0225]

While stirring the mixture, 180 g of pure water was added to the mixture to obtain a water-in-oil emulsion. The O/W volume ratio of the water-in-oil emulsion was 8/92 = 0.087.

[0226]

The obtained emulsion was quickly transferred to a reaction container, and after sealing, the monomer in the emulsion was polymerized under conditions of 60°C and 24 hours while being left to stand.

[0227]

After completion of the polymerization, the contents of the reaction container were taken out, coarsely crushed into 1 cm square, and then subjected to an extraction operation using methanol to obtain an extract. Thereafter, the obtained extract was dried under reduced pressure to obtain a dried product.

[0228]

The obtained dried product was immersed in dichloroethane containing zinc bromide, and subsequently stirred under a condition of 40°C for 24 hours, and then contacted with methanol, 4% hydrochloric acid, 4% aqueous sodium hydroxide solution, and water in this order to hydrolyze the dried product. The obtained hydrolysate was dried, pulverized, and classified to

obtain an organic porous body having a mass average particle size in a range from 500 to 850 μm. The organic porous body was used as a comparative water absorbent 1.

[0229]

Conclusion

The production conditions of Examples 1 to 6 and Comparative Examples 1 and 2, and the physical property values of the water absorbents 1 to 6 and the comparative water absorbent 1 measured and calculated by the above-described methods are presented in Tables 1 and 2 below.

[0230]

[Table 1]

Table 1: Production conditions of Examples 1 to 6 and Comparative Examples 1 to 2

	Rate of neutralization [mol%]	O/W volume ratio
Example 1	40	7.3
Example 2	50	7.3
Example 3	50	7.3
Example 4	50	3.2
Example 5	60	7.3
Example 6	50	7.3
Comparative Example 1	75	7.3
Comparative Example 2	100	0.087

[0231]

[Table 2]

Table 2: Physical property values of water absorbents 1 to 6 and comparative water absorbent 1

		CRC [g/g]	Bulk specific gravity [g/mL]	FSC [g/g]	Water separation percentage [%]	Vortex [sec]	pH	D50 [μm]	Fine powder increase amount [mass%]
Example 1	Water absorbent 1	19	0.09	61	68	0.7	4.7	554	- ★
Example 2	Water absorbent 2	21	0.08	73	72	0.8	5.2	524	7.3
Example 3	Water absorbent 3	19	0.16	43	56	3.6	5.2	542	- ★
Example 4	Water absorbent 4	23	0.17	42	45	3.9	5.2	478	- ★
Example 5	Water absorbent 5	21	0.09	73	71	0.5	5.6	488	- ★
Example 6	Water absorbent 6	20	0.09	77	74	0.7	5.1	520	- ★
Comparative Example 2	Comparative water absorbent 1	18	0.22	75	76	0.2	8.2	500-850	18.7

★ The symbol "-" in Table 2 means that the fine powder increase amount was not measured.

[0232]

As presented in Table 1, in the methods for producing a water absorbent of Examples 1 to 6, the rate of neutralization of the aqueous monomer solution is less than 70 mol%, and the O/W volume ratio of the O/W emulsion is 2.5 or more; thus, the methods satisfy the requirements for the production method of the present invention. Accordingly, the methods for producing a water absorbent of Examples 1 to 6 correspond to the production method of the present invention.

[0233]

In addition, since the rates of neutralization of the aqueous monomer solutions in Examples 1 to 6 are less than 70 mol%, it is clear that the rates of neutralization of the crosslinked polymers of the water absorbents 1 to 6 are also less than 70 mol%. Further, as presented in Table 2, the water absorbents 1 to 6 have a CRC of 5 to 25 g/g and a bulk specific gravity of less than 0.3 g/ml. Therefore, the water absorbents 1 to 6 correspond to the water absorbent of the present invention.

[0234]

Accordingly, the water absorbent of the present invention can be produced by the production method of the present invention.

[0235]

As presented in Table 2, the water absorbents 1 to 6 have a pH of 4.7 to 5.6, and are weakly acidic. Therefore, it is understood that the water absorbents 1 to 6 can reduce skin roughness and the like of a user as compared with known water absorbents. In addition, the water absorbents 1 to 6 have a sufficiently small Vortex value and a sufficiently high water separation percentage, and thus can be said to be excellent in both water absorption speed and water separation percentage.

[0236]

As described above, it was found that the water absorbent of the present invention can reduce skin roughness and the like of a user as compared with known water absorbents, and is excellent in both water absorption speed and water separation percentage. It was also found that the production method of the present invention can produce the water absorbent.

[0237]

In the known production method as presented in Comparative Example 1, a water absorbent could not be produced when the O/W volume ratio was 2.5 or more. On the other hand, from the comparison between Examples 1 to 6 and Comparative Example 1, it was presented that the production method of the present invention can produce a water absorbent even when the O/W volume ratio is 2.5 or more by adjusting the rate of neutralization of the aqueous monomer solution to less than 70 mol%.

Industrial Applicability

[0238]

The present invention can be preferably used for applications that require a reduction in skin roughness and the like of a user as compared with known water absorbents, and a high water absorption speed and a high water separation percentage. Examples of the applications can include use as a substitute for a hydrophilic fiber such as pulp typically used in sanitary materials such as disposable diapers, sanitary napkins, urine leakage pads such as water-absorbent shorts/pads, and breast milk pads, and use as a water-absorbent polymer of the sanitary materials. Examples of other applications include soil water retention agents, seedling-raising sheets, seed-coating materials, condensation prevention sheets, drip-absorbing materials, freshness-retaining materials, disposable handwarmers, cooling bandanas, cooling packs, medical waste liquid solidifying agents, residual soil solidification materials, water liquid waste gelling agents for damage prevention, water-absorbing sandbags, portable toilets for disasters, poultice materials, thickeners for cosmetics, water-stopping materials for electrical and electronic materials and communication cables, gasket packings, sustained-release agents for fertilizers, various sustained-release agents (space disinfectants, air fresheners, etc.), pet sheets, cat litter, dressing materials for wound protection, construction materials for condensation prevention, and agents for removing moisture from oil.

Reference Signs List

[0239]

1 First solvent

2 Aqueous monomer solution

3 Second solvent

4 O/W Emulsion

5 Organic porous body