as long as possible, particularly in the event that the organic compound having at least one positive charge is the product or an intermediate of the synthetic method which is synthesised with participation of a catalytic activity of the metabolically active cell.

These and other objects are achieved by the subject matter of the present application and particularly also by the subject matter of the accompanying independent claims, with embodiments arising from the dependent claims.

In one example, the problem underlying the disclosure is solved by a method for removing an organic compound from an aqueous solution, comprising the steps

a) providing the aqueous solution which contains the organic compound, and a hydrophobic organic solution, wherein the latter comprises a liquid hydrophobic cation exchanger,

b) contacting the aqueous solution and the hydrophobic organic solution, and

c) separating off the hydrophobic organic solution from the aqueous solution,

wherein the liquid hydrophobic cation exchanger is a saturated alkanoic acid having at least one alkyl substituent,

wherein the organic compound is an organic compound having at least one positive charge and a neutral or positive total charge.

In another example, the problem is solved by a method wherein the organic compound is a compound of the formula

$$NR^2R^3H^+\text{-}A\text{-}COOR^1 \text{ (I) or}$$

$$NR^2R^3H^+\text{-}A\text{-}\ NR^4R^5H^+ \text{ (II)},$$

wherein R^1 is hydrogen, methyl, ethyl, propyl, isopropyl or a negative charge,

wherein A is an alkylene group having at least three, preferably at least six, particularly preferably eight, carbon atoms, which is preferably unsubstituted and straight-chain,

and wherein R^2, R^3, R^4, and R^5, in each case and independently of one another, are selected from the group consisting of hydrogen, methyl, ethyl and propyl.

In another example, the problem is solved by a method wherein the pH in the aqueous solution in step b) is 6 to 8, preferably 6.2 to 7.2.

In another example, the problem is solved by a method wherein the amount-of-substance ratio of liquid cation exchanger to organic compound in step b) is at least 1.

In another example, the problem is solved by a method wherein the volumetric ratio of organic solution to aqueous solution is 1:10 to 10:1.

In another example, the problem is solved by a method wherein the liquid cation exchanger is a branched-chain fatty acid of the formula $(H_3C)_2CH-(CH_2)_n-COOH$ or an unprotonated form thereof and n is at least 4, preferably at least 8, and most preferably is 14.

In another example, the problem is solved by a method wherein the liquid cation exchanger is a saturated alkanoic acid having at least one alkyl substituent which preferably comprises in total at least 12 carbon atoms.

In another example, the problem is solved by a method wherein the aqueous solution additionally comprises a metabolically active cell.

In another example, the problem is solved by a method wherein the organic compound is a compound toxic to a cell, preferably a bacterial cell.

In another example, the problem is solved by a method wherein the organic solution additionally contains at least one organic solvent, preferably a fatty acid and/or a fatty acid ester.

In another example, the problem is solved by a method wherein the hydrophobic organic solution contains the liquid hydrophobic cation exchanger in a volumetric fraction of 20 to 80%, preferably 25 to 75%.

In another example, the organic compound is a diamine selected from the group consisting of 1,4-butanediamine, 1,5-pentanediamine, 1,6-hexanediamine, 1,8-octanediamine, 1,14-tetradecanediamine, 1,18-octadecanediamine, 2-methyl-1,5-diaminopentane, 2,2-dimethyl-1,5-diaminopentane, 4,4'-diaminodicyclohexylmethane, 3,3'-dimethyl-4,4'-diaminodicyclohexylmethane, 3,3',5,5'-tetramethyl-4,4'-diaminodicyclohexylmethane, m- or p-xylylenediamine, 2,2,4- or 2,4,4-trimethylhexamethylenediamine, 1,4-diaminocyclohexane, 4,4'-diaminodicyclohexylpropane, isophoronediamine, meta-xylylenediamine and para-xylylenediamine.

In another example, the temperature in step b) is between 28 and 70 °C, preferably between 30 and 37°C.

In another example, the problem underlying the disclosure is solved by a reaction mixture comprising an aqueous solution which contains an organic compound and a hydrophobic organic solution,

wherein the hydrophobic organic solution comprises a liquid hydrophobic cation exchanger,

wherein the liquid hydrophobic cation exchanger is a saturated alkanoic acid having at least one alkyl substituent,

and wherein the organic compound is an organic compound having at least one positive charge and a neutral or positive total charge.

In another example, the problem is solved by a reaction mixture wherein the organic compound is a compound of the formula

$$NR^2R^3H^+\text{-}A\text{-}COOR^1 \quad (I) \text{ or}$$

$$NR^2R^3H^+\text{-}A\text{-}\ NR^4R^5H^+ \quad (II),$$

wherein R^1 is hydrogen, methyl, ethyl, propyl, isopropyl or a negative charge,

wherein A is an alkylene group having at least three, preferably at least six, particularly preferably eight, carbon atoms which is preferably unsubstituted and straight-chain,

and wherein R^2, R^3, R^4, and R^5 in each case and independently of one another, are selected from the group consisting of hydrogen, methyl, ethyl and propyl.

In one aspect, the present disclosure refers to a reaction mixture, comprising an aqueous solution comprising an organic compound, and a hydrophobic organic solution comprising a liquid hydrophobic cation exchanger, wherein the liquid hydrophobic cation exchanger is a saturated alkanoic acid comprising an alkyl substituent which has at least 12 carbon atoms, and the organic compound is a compound of the formula (II)

$$NR^2R^3H^+\text{-}A\text{-}\ NR^4R^5H^+ \quad (II),$$

wherein A is an alkylene group comprising at least three carbon atoms, and R^2, R^3, R^4, and R^5, each independently, are selected from the group consisting of methyl, ethyl, propyl and butyl.

In another example, the problem is solved by a reaction mixture wherein the liquid hydrophobic cation exchanger is a branched-chain fatty acid of the formula

$(H_3C)_2CH-(CH_2)_n-COOH$ or an unprotonated form thereof and n is at least 4, preferably at least 8, and most preferably 14.

In another example, the liquid cation exchanger is a saturated alkanoic acid having at least one alkyl substituent which preferably comprises in total at least 12 carbon atoms.

In another example, the aqueous solution additionally comprises a metabolically active cell.

In another example, the organic compound is a diamine selected from the group consisting of 1,4-butanediamine, 1,5-pentanediamine, 1,6-hexanediamine, 1,8-octanediamine, 1,14-tetradecanediamine, 1,18-octadecanediamine, 2-methyl-1,5-diaminopentane, 2,2-dimethyl-1,5-diaminopentane, 4,4'-diaminodicyclohexylmethane, 3,3'-dimethyl-4,4'-diaminodicyclohexylmethane, 3,3',5,5'-tetramethyl-4,4'-diaminodicyclohexylmethane, m- or p-xylylenediamine, 2,2,4- or 2,4,4-trimethylhexamethylenediamine, 1,4-diaminocyclohexane, 4,4'-diaminodicyclohexylpropane, isophoronediamine, meta-xylylenediamine and para-xylylenediamine.

Further examples of the aspect comprise all examples of the method of the present disclosure.

The inventors of the present invention have found that the efficiency of the removal of an organic compound having a positive charge from an aqueous solution into a hydrophobic organic solution can surprisingly be increased if this organic solution comprises a liquid cation exchanger which is a saturated alkanoic acid having at least one alkyl substituent. Without wishing to be bound to any theory, the inventors of the present invention presume that the negative charge or the negative charges of the liquid cation exchanger interacts interact ionically with the one positive charge or the multiplicity of positive charges of the organic compounds and that this interaction leads to a masking of at least one positive charge, which increases the solubility in the organic phase.

The present invention provides the use of a saturated alkanoic acid having at least one alkyl substituent as a liquid hydrophobic cation exchanger for removing an organic compound having a positive charge from an aqueous solution, preferably with accumulation of the organic compound in the hydrophobic organic solution. In a preferred embodiment, the expression "saturated alkanoic acid having at least one alkyl substituent" is taken to mean an alkanoic acid

Claims

1. A reaction mixture, comprising
an aqueous solution comprising an organic compound,
and
a hydrophobic organic solution comprising a liquid hydrophobic cation exchanger,
wherein
the liquid hydrophobic cation exchanger is a saturated alkanoic acid comprising an alkyl substituent which has at least 12 carbon atoms, and
the organic compound is a compound of the formula (II)

$$NR^2R^3H^+\text{-}A\text{-}\ NR^4R^5H^+ \qquad \text{(II)},$$

wherein
A is an alkylene group comprising at least three carbon atoms, and
R^2, R^3, R^4, and R^5, each independently, are selected from the group consisting of methyl, ethyl, propyl and butyl.

2. The reaction mixture according to claim 1, wherein the liquid hydrophobic cation exchanger is a branched-chain fatty acid of formula $(H_3C)_2CH\text{-}(CH_2)_n\text{-}COOH$, or an unprotonated form thereof, and n is at least 4.

3. The reaction mixture according to claim 1, wherein the liquid cation exchanger is a branched-chain fatty acid which comprises substituents that are other than cyclic substituents.

4. The reaction mixture according to claim 1, wherein the aqueous solution further comprises a metabolically active cell.

5. The reaction mixture according to claim 1, wherein the organic compound is a diamine selected from the group consisting of 1,4-butanediamine, 1,5-pentanediamine, 1,6-hexanediamine, 1,8-octanediamine, 1,14-tetradecanediamine, 1,18-octadecanediamine, 2-methyl-1,5-diaminopentane, 2,2 dimethyl-1,5-diaminopentane, 4,4'-

diaminodicyclohexylmethane, 3,3'-dimethyl-4,4'-diaminodicyclohexylmethane, 3,3',5,5'-tetramethyl-4,4'-diaminodicyclohexylmethane, 2,2,4- or 2,4,4-trimethylhexamethylenediamine, 1,4-diaminocyclohexane, 4,4'-diaminodicyclohexylpropane, and isophoronediamine.

6. The reaction mixture according to claim 1, wherein a molar ratio of the liquid cation exchanger to the organic compound is at least 1.

7. The reaction mixture according to claim 1, wherein a molar ratio of the liquid cation exchanger to the organic compound is from 1.5 to 3.

8. The reaction mixture according to claim 1, wherein a volumetric ratio of the hydrophobic organic solution to the aqueous solution is 100:1 to 1:100.

9. The reaction mixture according to claim 1, wherein a volumetric ratio of the hydrophobic organic solution to the aqueous solution is 20:1 to 1:20.

10. The reaction mixture according to claim 1, wherein a volumetric ratio of the hydrophobic organic solution to the aqueous solution is 2:1 to 1:2.

Abstract

The present invention relates to a method for removing an organic compound from an aqueous solution, comprising the steps of providing the aqueous solution which contains the organic compound, and a hydrophobic organic solution, where the latter comprises a liquid hydrophobic cation exchanger, contacting the aqueous solution and the hydrophobic organic solution, and separating off the hydrophobic organic solution from the aqueous solution, wherein the liquid hydrophobic cation exchanger is a saturated alkanoic acid having at least one alkyl substituent, where the organic compound is an organic compound having at least one positive charge and a neutral or positive total charge.

[No Suitable Figure]