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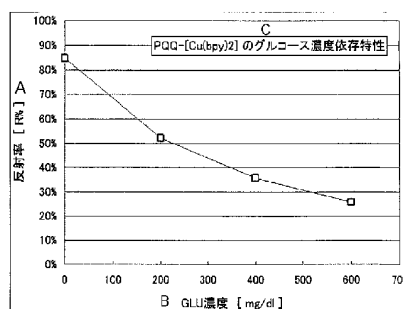
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[続葉有]

(54) Title: METHOD OF COLORIMETRY AND REAGENT FOR USE THEREIN

(54) 発明の名称: 比色分析方法およびそれに用いる試薬



A.. REFLECTANCE [R%]
B.. GLU CONCENTRATION [mg/dl]
C.. GLUCOSE CONCENTRATION DEPENDENCE OF
PQQ-[Cu(bpy)2]

(57) Abstract: A method of colorimetry by which reliable analysis can be easily performed in a short time. An aqueous solution containing a bipyridyl/copper complex and glucose dehydrogenase is infiltrated into a filter paper and this paper is dried. When a sample, e.g., blood, is dropped on this paper, the bipyridyl/copper complex assumes a red-brown color depending on the glucose concentration. The color is measured. Since this reaction is a one-stage reaction, it occurs in as short as up to 5 seconds. The found value is highly reliable because this reaction needs neither hydrogen peroxide nor oxygen.

[続葉有]

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(57) 要約:

短時間かつ簡単に信頼性ある分析が実施できる比色分析方法を提供する。

ビビリジル銅錯体およびグルコースデヒドロゲナーゼを含む水溶液をろ紙に含浸させ、乾燥させる。これに血液等の試料を点着すると、グルコース濃度に応じて、ビビリジル銅錯体が赤褐色に発色するから、これを測定する。この反応は、1段階の反応であるため、5秒以下の短時間で起こる。また、この反応は、過酸化水素および酸素を必要としないため、測定値の信頼性も高い。

Verification of Translation

National Phase of International Patent Application No. PCT/JP03/00026
in Australia

Title of the Invention:

METHOD OF COLORIMETRY AND REAGENT FOR USE
THEREIN

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DESCRIPTION

METHOD OF COLORIMETRY AND REAGENT FOR USE THEREIN

5 Technical Field

The present invention relates to a colorimetric method and a reagent used for the same.

Background Art

10 In the field of clinical or biochemical examinations, a colorimetric analysis is employed as a method for analyzing components such as glucose, cholesterol, or the like in a sample. For example, the colorimetric analysis of glucose is generally as follows: a glucose oxidase reacts with glucose (substrate) to generate gluconolactone and hydrogen peroxide; and the
15 hydrogen peroxide is detected by a coloring reagent, such as a Trinder's reagent, in the presence of peroxidase. This method, in which the concentration of a substrate is measured indirectly via hydrogen peroxide, is not limited to glucose, but also is used to analyze other components such as cholesterol.

20 However, the conventional colorimetric analysis involves the following problems. First, the time required for measurement is long because it takes a long time until a color reaction ends due to the indirect measurement of an analyte via hydrogen peroxide. For example, the measurement of glucose takes 30 to 60 seconds. Second, it is difficult to set conditions because two
25 different enzyme reaction systems should be stabilized simultaneously. Finally, the conventional colorimetric analysis requires oxygen, and inadequate oxygen supply may lead to an insufficient reaction.

Disclosure of Invention

30 It is an object of the present invention to provide a colorimetric method, and a reagent for use in that method, which overcome or at least alleviate one or more disadvantages of the prior art.

According to the present invention, there is provided a colorimetric method including:

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allowing an oxidoreductase to act on an analyte and a color-changeable substance that changes color by transferring an electron; and

performing a qualitative or quantitative analysis of the analyte by measuring color produced in the color-changeable substance due to electron transfer from the analyte to the color-changeable substance.

The present invention also provides a reagent used for the colorimetric method according to the preceding paragraph including:

an oxidoreductase; and
a color-changeable substance that changes color by transferring an electron.

With the foregoing in mind, it is an object of the present invention to provide a colorimetric method that has a single reaction system and can achieve a short-time analysis and provide reliable values with the analysis.

A colorimetric method of the present invention includes allowing an oxidoreductase to act on an analyte and a color-changeable substance that changes color by transferring an electron, and performing a qualitative or quantitative analysis of the analyte by measuring color produced in the color-changeable substance due to electron transfer from the analyte to the color-changeable substance.

This method has a single reaction system, so that the reaction system is simple and stable, and the time until a color reaction ends is short. Therefore, the measuring time is reduced (e.g., when glucose is used as an analyte, the measurement can be performed within about 5 seconds). Moreover, this method does not require hydrogen peroxide, and in principle is not affected by the amount of oxygen, thus ensuring highly reliable values with the analysis.

A reagent of the present invention is used for the above colorimetric method and includes an oxidoreductase and a color-changeable substance that changes color by transferring an electron. A test piece of the present invention includes this reagent. Compared with a conventional test piece for colorimetric analysis requiring hydrogen peroxide, the test piece of the present invention can achieve a very short-time analysis and ensure highly reliable values with the analysis.

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An analysis method that uses a bipyridyl metal complex as a light-emitting substance has been proposed (e.g., JP 10-253633 A). However, this method quite differs from the present invention in technical field because the present invention relates to a colorimetric method. Another technique that
5 allows a bipyridyl metal complex to produce/erase color by direct application from an electrode has been proposed (e.g., JP 57-192483 A). However, this technique also quite differs from the present invention in technical field because the present invention utilizes electron transfer by an oxidoreductase.

The preceding discussion of prior art is included to explain the context of
10 the invention. This is not to be taken as an admission that any of the material referred to was published, known or part of the common general knowledge in Australia as at the priority date of any of the claims.

Brief Description of Drawings

15 FIG. 1 is a graph showing the dependence of reflectance on glucose concentration in an example of the present invention.

FIG. 2 is a graph showing the dependence of reflectance on glucose concentration in another example of the present invention.

20 FIG. 3 is a graph showing a color change in yet another example of the present invention.

FIG. 4 is a graph showing a color change in still another example of the present invention.

FIG. 5 is a graph showing a color change in still another example of the
25 present invention.

FIG. 6 is a graph showing a color change in still another example of the present invention.

FIG. 7 is a graph showing the dependence of reflectance on glucose concentration in still another example of the present invention.

5 FIGS. 8A to 8F are graphs showing a color change in still another example of the present invention.

FIGS. 9A to 9D are graphs showing a color change in still another example of the present invention.

10 FIGS. 10A to 10C are graphs showing a color change in still another example of the present invention.

FIG. 11 is a graph showing a color change in still another example of the present invention.

FIG. 12 is a graph showing a color change in still another example of the present invention.

15 FIGS. 13A to 13C are graphs showing a color change in still another example of the present invention.

FIG. 14 is a graph showing a color change in still another example of the present invention.

20 FIG. 15 is a graph showing a color change in still another example of the present invention.

FIGS. 16A to 16E are graphs showing a color change in still another example of the present invention.

FIGS. 17A and 17B are graphs showing a color change in still another example of the present invention.

25 FIGS. 18A to 18C are graphs showing a color change in still another example of the present invention.

Best Mode for Carrying Out the Invention

30 In a colorimetric method, a reagent, and a test piece of the present invention, the color-changeable substance that changes color by transferring an electron is preferably a transition metal complex. The transition metal complex is preferably a copper complex, an iron complex, a ruthenium complex, an osmium complex, or a mixture containing at least two of these complexes. It is preferable that a coordinating atom of a ligand in the
35 transition metal complex is at least one selected from the group consisting of nitrogen, oxygen, and sulfur. It is preferable that the ligand is selected, e.g., from the group consisting of ammonia, a bipyridyl compound, an

imidazole compound, a phenanthroline compound, an ethylenediamine compound, amino acids, a triazine compound, a biquinoline compound, a pyridylazo compound, a nitroso compound, an oxine compound, a benzothiazole compound, an acetylacetone compound, an anthraquinone compound, a xanthene compound, oxalic acid, and a derivative of each of the compounds. At least one hydrogen atom that occupies a position other than the coordination position of the ligand may be replaced by a substituent. Examples of the substituent include an alkyl group, an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group, a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group. The transition metal complex may include two or more types of ligands, i.e., it can be a mixed ligand complex.

In a colorimetric method, a reagent, and a test piece of the present invention, the oxidoreductase is preferably a dehydrogenase or an oxidase. The reaction rate may increase with the amount of enzyme. The analyte is, e.g., glucose, cholesterol, uric acid, lactic acid, pyruvic acid, creatine, or creatinine. In this case, the oxidoreductase may be a dehydrogenase or an oxidase that corresponds to the respective analyte.

In a colorimetric method, a reagent, and a test piece of the present invention, it is preferable that a mediator is used in addition to the color-changeable substance that changes color by transferring an electron. Although the color-changeable substance can serve as a mediator, it has the function not only of transferring an electron but also changing color. Therefore, the additional mediator differs from the color-changeable substance. The mediator increases the speed of electron transfer, which in turn increases the speed of color change of the color-changeable substance. Thus, it is possible to use less oxidoreductase and obtain a cost advantage. The mediator is, e.g., an osmium complex, a ruthenium complex, or the like. Specific examples of the mediator will be described later. When the color-changeable substance is used with the mediator, it is preferable that a copper complex is used as the color-changeable substance, and an osmium or a ruthenium complex is used as the mediator.

A test piece of the present invention preferably includes an inorganic gel as well as the reagent. The color-changeable substance that changes color by transferring an electron is reduced by electron transfer and thus

changes color. However, when oxygen is present in the surroundings, the color may fade due to reoxidation of the color-changeable substance. The inorganic gel can be useful to prevent the fading.

Hereinafter, the present invention will be described in more detail

5 by way of specific examples.

As described above, the color-changeable substance that changes color by transferring an electron is preferably a transition metal complex in the present invention. Among the transition metal complexes particularly suitable for the color-changeable substance are a copper complex, an iron

10 complex, a ruthenium complex, and an osmium complex.

Copper complex

The color of the copper complex is changed, e.g., from blue (Cu^{2+}) to reddish brown (Cu^+) by electron transfer that is caused by an enzyme.

Examples of a ligand in the copper complex include ammonia, a bipyridyl
15 compound, an imidazole compound, a phenanthroline compound, an ethylenediamine compound, amino acids, a triazine compound, a biquinoline compound, a pyridylazo compound, a nitroso compound, an oxine compound, a benzothiazole compound, an acetylacetone compound, an anthraquinone compound, a xanthene compound, oxalic acid, and a derivative of each of the
20 compounds. A mixed ligand with two or more types of these ligands may be used.

For the bipyridyl compound, the coordination number is 4 or 6. In view of stability, two bipyridyls should be coordinated at two coordination positions in the complex, respectively. Hydrogen atoms binding to the
25 pyridine rings may be unsubstituted or substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex. Examples of the position of the substituent include the 4,4'-position and 5,5'-position. Examples of the substituent include an alkyl group (such as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl group, a phenyl group, a hydroxyl
30 group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group
35 (such as bromine, chlorine, or iodine).

Examples of a bipyridyl copper complex include $[\text{Cu}(\text{bipyridyl})_2]$, $[\text{Cu}(4,4'\text{-dimethyl-2,2'-bipyridyl})_2]$, $[\text{Cu}(4,4'\text{-diphenyl-2,2'-bipyridyl})_2]$,

- [Cu(4,4'-diamino-2,2'-bipyridyl)₂], [Cu(4,4'-dihydroxy-2,2'-bipyridyl)₂],
 [Cu(4,4'-dicarboxy-2,2'-bipyridyl)₂], [Cu(4,4'-dibromo-2,2'-bipyridyl)₂],
 [Cu(5,5'-dimethyl-2,2'-bipyridyl)₂], [Cu(5,5'-diphenyl-2,2'-bipyridyl)₂],
 [Cu(5,5'-diamino-2,2'-bipyridyl)₂], [Cu(5,5'-dihydroxy-2,2'-bipyridyl)₂],
 5 [Cu(5,5'-dicarboxy-2,2'-bipyridyl)₂], [Cu(5,5'-dibromo-2,2'-bipyridyl)₂],
 [Cu(bipyridyl)₃], [Cu(4,4'-dimethyl-2,2'-bipyridyl)₃],
 [Cu(4,4'-diphenyl-2,2'-bipyridyl)₃], [Cu(4,4'-diamino-2,2'-bipyridyl)₃],
 [Cu(4,4'-dihydroxy-2,2'-bipyridyl)₃], [Cu(4,4'-dicarboxy-2,2'-bipyridyl)₃],
 [Cu(4,4'-dibromo-2,2'-bipyridyl)₃], [Cu(5,5'-dimethyl-2,2'-bipyridyl)₃],
 10 [Cu(5,5'-diphenyl-2,2'-bipyridyl)₃], [Cu(5,5'-diamino-2,2'-bipyridyl)₃],
 [Cu(5,5'-dihydroxy-2,2'-bipyridyl)₃], [Cu(5,5'-dicarboxy-2,2'-bipyridyl)₃], and
 [Cu(5,5'-dibromo-2,2'-bipyridyl)₃].

For the imidazole compound, the coordination number is 4.

- Hydrogen atoms binding to the imidazole rings may be unsubstituted or
 15 substituted. The introduction of a substituent makes it possible to control,
 e.g., the solubility and oxidation-reduction potential of the complex.
 Examples of the position of the substituent include the 2-position, 4-position
 and 5-position. Examples of the substituent include an alkyl group (such
 as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl
 20 group, a phenyl group, a hydroxyl group, an alkoxy group (such as a
 methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a
 sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary
 amine, a secondary amine, a tertiary amine, an amino group, an acyl group,
 an amido group, and a halogen group (such as bromine, chlorine, or iodine).
 25 Examples of an imidazole copper complex include [Cu(imidazole)₄],
 [Cu(4-methyl-imidazole)₄], [Cu(4-phenyl-imidazole)₄],
 [Cu(4-amino-imidazole)₄], [Cu(4-hydroxy-imidazole)₄],
 [Cu(4-carboxy-imidazole)₄], and [Cu(4-bromo-imidazole)₄].

- The amino acids include, e.g., arginine (L-Arg). A copper complex
 30 containing arginine generally has the advantage of high solubility. The
 mixed ligand may be a combination of the bipyridyl compounds and the
 imidazole compounds or a combination of the bipyridyl compounds and the
 amino acids, such as [Cu(imidazole)₂(bipyridyl)] or [Cu(L-Arg)₂(bipyridyl)].
 The mixed ligand can be used to impart various properties to the complex,
 35 e.g., arginine improves the solubility of the complex.

Iron complex

The color of the iron complex is changed, e.g., from yellow (Fe³⁺) to

red (Fe^{2+}) by electron transfer that is caused by an enzyme. Examples of a ligand in the iron complex include ammonia, a bipyridyl compound, an imidazole compound, a phenanthroline compound, an ethylenediamine compound, amino acids, a triazine compound, a biquinoline compound, a pyridylazo compound, a nitroso compound, an oxine compound, a benzothiazole compound, an acetylacetone compound, an anthraquinone compound, a xanthene compound, oxalic acid, and a derivative of each of the compounds. A mixed ligand with two or more types of these ligands may be used.

- 10 For the bipyridyl compound, the coordination number is 6. Hydrogen atoms binding to the pyridine rings may be unsubstituted or substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex. Examples of the position of the substituent include the 4,4'-position and
- 15 5,5'-position. Examples of the substituent include an alkyl group (such as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary
- 20 amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group (such as bromine, chlorine, or iodine).

Examples of a bipyridyl iron complex include $[\text{Fe}(\text{bipyridyl})_3]$, $[\text{Fe}(4,4'\text{-dimethyl-2,2'-bipyridyl})_3]$, $[\text{Fe}(4,4'\text{-diphenyl-2,2'-bipyridyl})_3]$, $[\text{Fe}(4,4'\text{-diamino-2,2'-bipyridyl})_3]$, $[\text{Fe}(4,4'\text{-dihydroxy-2,2'-bipyridyl})_3]$, $[\text{Fe}(4,4'\text{-dicarboxy-2,2'-bipyridyl})_3]$, $[\text{Fe}(4,4'\text{-dibromo-2,2'-bipyridyl})_3]$, $[\text{Fe}(5,5'\text{-dimethyl-2,2'-bipyridyl})_3]$, $[\text{Fe}(5,5'\text{-diphenyl-2,2'-bipyridyl})_3]$, $[\text{Fe}(5,5'\text{-diamino-2,2'-bipyridyl})_3]$, $[\text{Fe}(5,5'\text{-dihydroxy-2,2'-bipyridyl})_3]$, $[\text{Fe}(5,5'\text{-dicarboxy-2,2'-bipyridyl})_3]$, and $[\text{Fe}(5,5'\text{-dibromo-2,2'-bipyridyl})_3]$.

- For the imidazole compound, the coordination number is 6.
- 30 Hydrogen atoms binding to the imidazole rings may be unsubstituted or substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex. Examples of the position of the substituent include the 2-position, 4-position and 5-position. Examples of the substituent include an alkyl group (such
- 35 as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a

sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group (such as bromine, chlorine, or iodine).

Examples of an imidazole iron complex include $[\text{Fe}(\text{imidazole})_6]$,

- 5 $[\text{Fe}(4\text{-methyl-imidazole})_6]$, $[\text{Fe}(4\text{-phenyl-imidazole})_6]$,
 $[\text{Fe}(4\text{-amino-imidazole})_6]$, $[\text{Fe}(4\text{-hydroxy-imidazole})_6]$,
 $[\text{Fe}(4\text{-carboxy-imidazole})_6]$, and $[\text{Fe}(4\text{-bromo-imidazole})_6]$.

- The amino acids include, e.g., arginine (L-Arg). An iron complex containing arginine generally has the advantage of high solubility. The
 10 mixed ligand may be a combination of the bipyridyl compounds and the imidazole compounds or a combination of the bipyridyl compounds and the amino acids, such as $[\text{Fe}(\text{imidazole})_2(\text{bipyridyl})_2]$ or $[\text{Fe}(\text{L-Arg})_2(\text{bipyridyl})_2]$. The mixed ligand can be used to impart various properties to the complex, e.g., arginine improves the solubility of the complex.

15 *Ruthenium complex*

- Examples of a ligand in the ruthenium complex include ammonia, a bipyridyl compound, an imidazole compound, a phenanthroline compound, an ethylenediamine compound, amino acids, a triazine compound, a
 20 biquinoline compound, a pyridylazo compound, a nitroso compound, an oxine compound, a benzothiazole compound, an acetylacetone compound, an anthraquinone compound, a xanthene compound, oxalic acid, and a derivative of each of the compounds. A mixed ligand with two or more types of these ligands may be used.

For the bipyridyl compound, the coordination number is 6.

- 25 Hydrogen atoms binding to the pyridine rings may be unsubstituted or substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex. Examples of the position of the substituent include the 4,4'-position and 5,5'-position. Examples of the substituent include an alkyl group (such as a
 30 methyl group, an ethyl group, or a propyl group), an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group,
 35 an amido group, and a halogen group (such as bromine, chlorine, or iodine).

Examples of a bipyridyl ruthenium complex include $[\text{Ru}(\text{bipyridyl})_3]$, $[\text{Ru}(4,4'\text{-dimethyl-2,2'-bipyridyl})_3]$, $[\text{Ru}(4,4'\text{-diphenyl-2,2'-bipyridyl})_3]$,

- [Ru(4,4'-diamino-2,2'-bipyridyl)₃], [Ru(4,4'-dihydroxy-2,2'-bipyridyl)₃],
 [Ru(4,4'-dicarboxy-2,2'-bipyridyl)₃], [Ru(4,4'-dibromo-2,2'-bipyridyl)₃],
 [Ru(5,5'-dimethyl-2,2'-bipyridyl)₃], [Ru(5,5'-diphenyl-2,2'-bipyridyl)₃],
 [Ru(5,5'-diamino-2,2'-bipyridyl)₃], [Ru(5,5'-dihydroxy-2,2'-bipyridyl)₃],
 5 [Ru(5,5'-dicarboxy-2,2'-bipyridyl)₃], and [Ru(5,5'-dibromo-2,2'-bipyridyl)₃].

For the imidazole compound, the coordination number is 6.

Hydrogen atoms binding to the imidazole rings may be unsubstituted or substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex.

- 10 Examples of the position of the substituent include the 2-position, 4-position and 5-position. Examples of the substituent include an alkyl group (such as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a
 15 sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group (such as bromine, chlorine, or iodine).

Examples of an imidazole ruthenium complex include

- [Ru(imidazole)₆], [Ru(4-methyl-imidazole)₆], [Ru(4-phenyl-imidazole)₆]
 20 [Ru(4-amino-imidazole)₆], [Ru(4-hydroxy-imidazole)₆],
 [Ru(4-carboxy-imidazole)₆], and [Ru(4-bromo-imidazole)₆].

The amino acids include, e.g., arginine (L-Arg). A ruthenium complex containing arginine generally has the advantage of high solubility. The mixed ligand may be a combination of the bipyridyl compounds and the
 25 imidazole compounds or a combination of the bipyridyl compounds and the amino acids, such as [Ru(imidazole)₂(bipyridyl)₂] or [Ru(L-Arg)₂(bipyridyl)₂]. The mixed ligand can be used to impart various properties to the complex, e.g., arginine improves the solubility of the complex.

Osmium complex

- 30 The color of the osmium complex is changed, e.g., from orange (Os³⁺) to dark brown (Os²⁺) by electron transfer that is caused by an enzyme. Examples of a ligand in the osmium complex include ammonia, a bipyridyl compound, an imidazole compound, a phenanthroline compound, an ethylenediamine compound, amino acids, a triazine compound, a biquinoline
 35 compound, a pyridylazo compound, a nitroso compound, an oxine compound, a benzothiazole compound, an acetylacetone compound, an anthraquinone compound, a xanthene compound, oxalic acid, and a derivative of each of the

compounds. A mixed ligand with two or more types of these ligands may be used.

For the bipyridyl compound, the coordination number is 6.

Hydrogen atoms binding to the pyridine rings may be unsubstituted or

- 5 substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex. Examples of the position of the substituent include the 4,4'-position and 5,5'-position. Examples of the substituent include an alkyl group (such as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl
- 10 group, a phenyl group, a hydroxyl group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group (such as bromine, chlorine, or iodine).

- 15 Examples of a bipyridyl osmium complex include $[\text{Os}(\text{bipyridyl})_3]$, $[\text{Os}(4,4'\text{-dimethyl-2,2'-bipyridyl})_3]$, $[\text{Os}(4,4'\text{-diphenyl-2,2'-bipyridyl})_3]$, $[\text{Os}(4,4'\text{-diamino-2,2'-bipyridyl})_3]$, $[\text{Os}(4,4'\text{-dihydroxy-2,2'-bipyridyl})_3]$, $[\text{Os}(4,4'\text{-dicarboxy-2,2'-bipyridyl})_3]$, $[\text{Os}(4,4'\text{-dibromo-2,2'-bipyridyl})_3]$, $[\text{Os}(5,5'\text{-dimethyl-2,2'-bipyridyl})_3]$, $[\text{Os}(5,5'\text{-diphenyl-2,2'-bipyridyl})_3]$, $[\text{Os}(5,5'\text{-diamino-2,2'-bipyridyl})_3]$, $[\text{Os}(5,5'\text{-dihydroxy-2,2'-bipyridyl})_3]$, $[\text{Os}(5,5'\text{-dicarboxy-2,2'-bipyridyl})_3]$, and $[\text{Os}(5,5'\text{-dibromo-2,2'-bipyridyl})_3]$.
- 20

For the imidazole compound, the coordination number is 6.

Hydrogen atoms binding to the imidazole rings may be unsubstituted or

- 25 substituted. The introduction of a substituent makes it possible to control, e.g., the solubility and oxidation-reduction potential of the complex. Examples of the position of the substituent include the 2-position, 4-position and 5-position. Examples of the substituent include an alkyl group (such as a methyl group, an ethyl group, or a propyl group), an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group (such as a methoxy group or an ethoxy group), a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary
- 30 amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group (such as bromine, chlorine, or iodine).

- 35 Examples of an imidazole osmium complex include $[\text{Os}(\text{imidazole})_6]$, $[\text{Os}(4\text{-methyl-imidazole})_6]$, $[\text{Os}(4\text{-phenyl-imidazole})_6]$, $[\text{Os}(4\text{-amino-imidazole})_6]$, $[\text{Os}(4\text{-hydroxy-imidazole})_6]$, $[\text{Os}(4\text{-carboxy-imidazole})_6]$, and $[\text{Os}(4\text{-bromo-imidazole})_6]$.

The amino acids include, e.g., arginine (L-Arg). An osmium complex containing arginine generally has the advantage of high solubility. The mixed ligand may be a combination of the bipyridyl compounds and the imidazole compounds or a combination of the bipyridyl compounds and the amino acids, such as $[\text{Os}(\text{imidazole})_2(\text{bipyridyl})_2]$ or $[\text{Os}(\text{L-Arg})_2(\text{bipyridyl})_2]$. The mixed ligand can be used to impart various properties to the complex, e.g., arginine improves the solubility of the complex.

The above explanation of the transition metal complexes is based on the type of transition metal, and the present invention is not limited thereto. Hereinafter, the transition metal complexes will be described based on their ligands.

A ligand that contains coordinating atoms N, O, and S has groups such as $=\text{N}-\text{OH}$, $-\text{COOH}$, $-\text{OH}$, $-\text{SH}$, and $>\text{C}=\text{O}$ in the molecule. Examples of metal complexes including this type of ligand are NN chelate, NO chelate, NS chelate, OO chelate, OS chelate, SS chelate (bidentate), N chelate (unidentate), and NNN chelate (tridentate). The combination is diverse. When a ligand has a double bond, Cu, Fe, Ru, and Os of the complex tend to have the function of transferring electrons. The ligand preferably has an aromatic ring. The ligand may be any of the above substituents. For example, the introduction of a sulfone group can improve the solubility of the metal complex. The metal complex may be formed by mixing two or more types of ligands and used as a mixed ligand complex. For example, when one of the ligands is amino acids, the metal complex may have a good affinity with an enzyme. Moreover, various halogen atoms (such as Cl, F, Br, and I) can be attached to part of the site of the central metal. The following is an example of the transfer metal complexes that are classified by the type of coordination.

NN coordination form

Phenanthroline derivative

- 30 Cu + 1,10-phenanthroline
- Fe + 1,10-phenanthroline
- Cu + bathophenanthroline
- Fe + bathophenanthroline
- Cu + bathophenanthroline sulfonic acid
- 35 Fe + bathophenanthroline sulfonic acid

Bipyridyl derivative

- Cu + 2,2'-bipyridyl
- Fe + 2,2'-bipyridyl

- Fe + 4,4'-diamino-2,2'-bipyridyl
 Ru + 4,4'-diamino-2,2'-bipyridyl
 Triazine derivative
 Cu + TPTZ (2,4,6-tripyridyl-S-triazine)
 5 Fe + TPTZ (2,4,6-tripyridyl-S-triazine)
 Fe + PDTZ (3-(2-pyridyl)-5,6-bis(4-sulfophenyl)-1,2,4-triazine)
 Biquinoline derivative
 Cu + cuproin (2,2'-biquinoline)
 Pyridylazo derivative
 10 Fe + nitro-PAPS (2-(5-nitro-2-pyridylazo)-5-[N-n-propyl-N-(3-sulfopropyl) amino] phenol)
NO coordination form
 Fe + nitroso-PSAP (2-nitroso-5-[N-n-propyl-N-(3-sulfopropyl) amino] phenol)
 15 Fe + nitroso-ESAP (2-nitroso-5-[N-ethyl-N-(3-sulfopropyl) amino] phenol)
 Fe + 1-nitroso-2-naphthol
NS coordination form
 Fe + 2-amino-4-thiazole acetic acid
OO coordination form
 20 Fe + 1,2-naphthoquinone-4-sulfonic acid
Mixed ligand form
 Os + Cl, imidazole, 4,4'-dimethyl-2,2'-bipyridyl
 Os + imidazole, 4,4'-dimethyl-2,2'-bipyridyl
 Cu + L-arginine, 2,2'-bipyridyl
 25 Cu + ethylenediamine, 2,2'-bipyridyl
 Cu + imidazole, 2,2'-bipyridyl

Next, the colorimetric method of the present invention is applied to a test piece. In this case, a copper complex is used as the color-changeable substance that changes color by transferring an electron, and glucose is
 30 used as the analyte. Other analytes such as cholesterol are analyzed basically in the same manner except that the oxidoreductase is changed in accordance with the analytes.

First, a bipyridyl copper complex is prepared either by using a commercially available product or by employing the following manner. For
 35 example, CuCl₂ and 2,2'-bipyridyl (bpy) are mixed in a water bath at about 60°C to 90°C and synthesized into [Cu(bpy)₂]Cl₂. The molar ratio of CuCl₂ to 2,2'-bipyridyl (bpy) is, e.g., 1 : 2. The concentration of the aqueous solution of bipyridyl copper complex ranges, e.g., from 1 to 10 wt%. A binder is dissolved in the aqueous solution of bipyridyl copper complex, and

then glucose dehydrogenase (GDH) is dissolved in the binder solution, thus producing a reagent solution. Examples of the binder include hydroxypropylcellulose (HPC), polyvinyl alcohol (PVA), polyvinyl pyrrolidone (PVP), polyacrylamide, and bovine serum albumin (BSA), and HPC is preferred. The concentration of the binder ranges, e.g., from 0.5 to 5 wt%. The concentration of GDH ranges, e.g., from 1000 to 50000 U/ml. A porous sheet (e.g., a filter paper) is impregnated with the reagent solution and dried, so that a test piece for glucose analysis can be produced. Before impregnation of the reagent solution, it is preferable that the porous sheet is impregnated with an inorganic gel solution and dried. The inorganic gel can be smectite or the like. The concentration of the inorganic gel in the solution ranges, e.g., from 1 to 5 wt%, preferably 1 to 3 wt%, and more preferably 1.5 to 2 wt%. The inorganic gel solution also may include an amphoteric surfactant such as CHAPS. The concentration of the amphoteric surfactant with respect to the total inorganic gel solution ranges, e.g., from 0.1 to 2 wt%, preferably 0.1 to 1 wt%, and more preferably 0.2 to 0.4 wt%. The amount of inorganic gel impregnated into the porous sheet ranges, e.g., from 1 to 50 mg/cm³, preferably 10 to 30 mg/cm³, and more preferably 15 to 20 mg/cm³, when measured on the basis of the volume of voids in the porous sheet. The porous sheet can be an asymmetrical porous film in which pore sizes vary in the thickness direction or in the sheet surface direction. The original color of this test piece is blue. When a sample containing glucose (e.g., blood) is applied to the test piece, the color changes to reddish brown in accordance with the glucose concentration. Therefore, the qualitative or quantitative analysis of the glucose can be performed using the color change. The time required for the analysis is about 2 to 3 seconds after the application of the sample. If the test piece is impregnated with an inorganic gel, it is possible to prevent fading caused by reoxidation after the color change and, e.g., to increase the time from the end of a color reaction to the start of measuring the color thus produced.

The inorganic gel is preferably selected from swelling clay minerals. Among the swelling clay minerals, bentonite, smectite, vermiculite, or synthetic fluorine mica is more preferred. In particular, synthetic smectite such as synthetic hectorite or synthetic saponite, or synthetic mica (the natural mica generally is a non-swelling clay mineral) such as swelling synthetic mica (or Na mica) typified by synthetic fluorine mica is preferred.

Next, the colorimetric method of the present invention is applied to

liquid system analysis. In this case, a copper complex is used as the color-changeable substance that changes color by transferring an electron, and glucose is used as the analyte. Other analytes such as cholesterol are analyzed basically in the same manner except that the oxidoreductase is changed in accordance with the analytes.

First, a copper complex $[\text{Cu}(\text{bpy})_2]\text{Cl}_2$ is synthesized in such a manner as described above. Then, a reagent solution is prepared by dissolving the copper complex and GDH in a buffer solution. Although they may be dissolved in water, the buffer solution is preferred. The pH of the buffer solution ranges, e.g., from 6 to 8, and preferably 6.5 to 7. The concentration of the copper complex ranges, e.g., from 0.1 to 60 mM, preferably 0.2 to 10 mM, and more preferably 0.3 to 0.6 mM. The concentration of GDH ranges, e.g., from 10 to 1000 U/ml, preferably 50 to 500 U/ml, and more preferably 100 to 200 U/ml. When a sample containing glucose (e.g., blood) is added to the reagent solution, the color of the reagent solution changes from blue to reddish brown in accordance with the glucose concentration in a short time, e.g., 5 seconds or less. This change may be observed visually or measured with an optical measuring device such as a spectrophotometer. The amount of the added sample ranges, e.g., from 1 to 100 μl , preferably 3 to 10 μl , and more preferably 5 to 10 μl with respect to 1 ml of the reagent solution.

As described above, it is preferable that a mediator such as an osmium complex or a ruthenium complex is used in addition to the color-changeable substance that changes color by transferring an electron in the colorimetric method of the present invention. For a test piece, the amount of mediator with respect to the total reagent solution ranges, e.g., from 0.1 to 50 mM, preferably 0.5 to 10 mM, and more preferably 1 to 3 mM. For liquid system analysis, the amount of mediator with respect to the total reagent solution ranges, e.g., from 0.1 to 10 mM, preferably 0.1 to 1 mM, and more preferably 0.1 to 0.3 mM. These ranges of optimum concentration depend on the type of mediator to be used.

Examples

Hereinafter, examples of the present invention will be described. In each of the examples, PQQ represents pyrroloquinoline quinone, and other reagents are explained in detail in the following table.

Reagent	Manufacturer	Note (name, etc.)
PQQGDH	TOYOBO Co., Ltd	PQQ-glucose dehydrogenase
GOD	Sigma	Glucose oxidase type X-S
Pyruvate oxidase	BoehringerMannheim	
Glucose	Wako Pure Chemical Industries, Ltd.	D(+)-glucose
Pyruvic acid	Wako Pure Chemical Industries, Ltd.	Lithium pyruvate monohydrate

Example 1

- An aqueous solution of $[\text{Cu}(\text{bpy})_2]\text{Cl}_2 \cdot 6\text{H}_2\text{O}$ (80 mM) was prepared by mixing CuCl_2 and 2,2'-bipyridyl at a molar ratio of 1 : 2 in a water bath at about 80°C. HPC-M was dissolved in the aqueous solution of bipyridyl copper complex at 2 wt%, and then was heated to 50°C and cooled to 25°C. Further, GDH was dissolved in this aqueous solution at 50000 U/ml, thus producing a reagent solution. Next, an asymmetrical porous film ("BTS-25", manufactured by US Filter) in which pore sizes vary in the thickness direction was impregnated from the surface that includes smaller pores with 2 wt% of an aqueous solution of inorganic gel ("Laponite XLG", manufactured by Rockwood Additives Limited), and then was dried. Moreover, 2 μl of the reagent solution was applied to the surface of the porous film that includes larger pores, and then was air-dried to form a circular spot (light blue). This spot portion was cut and sandwiched between PET films with holes, so that an intended test piece for glucose analysis was obtained.

- Serum having four different glucose concentrations (0 mg/ml, 2 mg/ml, 4 mg/ml, and 6 mg/ml) was applied to the test piece, and color produced in the test piece was measured after 5 seconds from the application by using a reflectance measuring device (wavelength: 470 nm). The graph in FIG. 1 shows the results. As shown in FIG. 1, the test piece produced color in accordance with the glucose concentration within 5 seconds from the application. This color (reddish brown) corresponding to the glucose concentration also was observed visually. The time required for producing the color was 2 to 3 seconds. The glucose-containing serum was prepared in the following manner. Human blood plasma was glycolyzed completely, frozen, and melted to produce serum. Then, glucose was added

to the serum in different concentrations as described above.

Example 2

Copper (II) chloride (0.01 mol) was dissolved in hot water (30 ml), to which 2,2'-bipyridyl (0.02 mol) was added and stirred. Then, the solution was cooled to precipitate hexahydrate as crystals, thus producing [Cu(bpy)₂]Cl₂·6H₂O. The following reaction reagent (1 ml) including this copper complex was placed in a microcell having an optical path length of 10 mm, and the absorption spectrum at a wavelength of 300 nm to 900 nm was measured with a spectrophotometer ("V-550", manufactured by JASCO Corporation) and identified as a blank (oxidized). A 500 mM glucose aqueous solution (10 µl) was added to the microcell while stirring, and the spectrum was measured immediately. The graph in FIG. 2 shows the results. As shown in FIG. 2, the copper complex was reduced by the enzyme reaction, and the color production was observed in a short wavelength region.

Reaction reagent composition

[Cu(bpy) ₂]Cl ₂	0.4 mM
PIPES (pH 7.0)	50 mM
PQQGDH	200 U/ml

Example 3

Copper (II) chloride (0.01 mol) and 2,2'-bipyridyl (0.033 mol) were added to a small amount of water and heated until they were dissolved completely. Then, the solution was cooled to precipitate [Cu(bpy)₃]Cl₂·6H₂O as crystals. The following reaction reagent (1 ml) including this copper complex was placed in a microcell having an optical path length of 10 mm, and the absorption spectrum at a wavelength of 300 nm to 900 nm was measured with a spectrophotometer ("V-550", manufactured by JASCO Corporation) and identified as a blank (oxidized). A 500 mM glucose aqueous solution (10 µl) was added to the microcell while stirring, and the spectrum was measured immediately. The graph in FIG. 3 shows the results. As shown in FIG. 3, the copper complex was reduced by the enzyme reaction, and the color production was observed in a short wavelength region.

Reaction reagent composition

[Cu(bpy) ₃]Cl ₂	0.4 mM
PIPES (pH 7.0)	50 mM
PQQGDH	200 U/ml

Example 4

Copper (II) chloride (0.01 mol) was dissolved in hot water (10 ml), ethylenediamine (en, 0.01 mol) was dissolved in hot water (10 ml), and 2,2'-bipyridyl (0.01 mol) was dissolved in hot ethanol (10 ml). The three solutions were mixed together to make a blue solution. This solution was cooled and concentrated, thus producing needle crystals of $[\text{Cu}(\text{en})(\text{bpy})]\text{Cl}_2$. The following reaction reagent (1 ml) including this copper complex was placed in a microcell having an optical path length of 10 mm, and the absorption spectrum at a wavelength of 300 nm to 900 nm was measured with a spectrophotometer ("V-550", manufactured by JASCO Corporation) and identified as a blank (oxidized). A 500 mM glucose aqueous solution (10 μl) was added to the microcell while stirring, and the spectrum was measured immediately. The graph in FIG. 4 shows the results. As shown in FIG. 4, the copper complex was reduced by the enzyme reaction, and the color production was observed in a short wavelength region.

Reaction reagent

$[\text{Cu}(\text{en})(\text{bpy})]\text{Cl}_2$	0.4 mM
PIPES (pH 7.0)	50 mM
PQQGDH	200 U/ml

Example 5

An aqueous solution of copper chloride was prepared by dissolving 511 mg (3.0 mmol, 1.0 eq.) of copper (II) chloride dihydrate in hot water (10 mL). Further, 408 mg (6.0 mmol, 2.0 eq.) of imidazole was dissolved in water (10 mL) and 69 mg (3.0 mmol, 1.0 eq.) of 2,2'-bipyridyl was dissolved in ethanol (10 mL), and then the two solutions were mixed together. This mixed solution was added to the aqueous solution of copper chloride, thus producing a deep blue solution of $[\text{Cu}(\text{Him})_2(\text{bpy})]\text{Cl}_2$. The following reaction reagent (1 ml) including this copper complex was placed in a microcell having an optical path length of 10 mm, and the absorption spectrum at a wavelength of 300 nm to 900 nm was measured with a spectrophotometer ("V-550", manufactured by JASCO Corporation) and identified as a blank (oxidized). A 500 mM glucose aqueous solution (10 μl) was added to the microcell while stirring, and the spectrum was measured immediately. The graph in FIG. 5 shows the results. As shown in FIG. 5, the copper complex was reduced by the enzyme reaction, and the color production was observed in a short wavelength region.

Reaction reagent

[Cu(Him) ₂ (bpy)]Cl ₂	1 mM
PIPES (pH 7.0)	50 mM
PQQGDH	1000 U/ml

Example 6

- 5 Copper (II) chloride (0.01 mol) was dissolved in hot water (10 ml),
L-arginine (0.01 mol) was dissolved in hot water (10 ml), and 2,2'-bipyridyl
(0.01 mol) was dissolved in hot ethanol (10 ml). The three solutions were
mixed together to make a deep blue solution. This solution was cooled and
concentrated, thus producing needle crystals of [Cu(L-Arg)(bpy)]Cl₂. The
10 following reaction reagent (1 ml) including this copper complex was placed
in a microcell having an optical path length of 10 mm, and the absorption
spectrum at a wavelength of 300 nm to 900 nm was measured with a
spectrophotometer ("V-550", manufactured by JASCO Corporation) and
identified as a blank (oxidized). A 500 mM glucose aqueous solution (10 µl)
15 was added to the microcell while stirring, and the spectrum was measured
immediately. The graph in FIG. 6 shows the results. As shown in FIG. 6,
the copper complex was reduced by the enzyme reaction, and the color
production was observed in a short wavelength region.

Reaction reagent

20 [Cu(L-Arg)(bpy)]Cl ₂	1 mM
PIPES (pH 7.0)	50 mM
PQQGDH	1000 U/ml

Example 7

- 25 An asymmetrical porous film ("BTS-25", manufactured by US
Filter) in which pore sizes vary in the thickness direction was impregnated
from the surface that includes smaller pores with 2 wt% of an aqueous
solution of inorganic gel having the following composition, and then was
dried. Moreover, 2 µl of a reagent solution having the following
composition was applied to the surface of the porous film that includes
30 larger pores, and then was air-dried to form a circular spot (light blue).
This spot portion was cut and sandwiched between PET films with holes, so
that an intended test piece for glucose analysis was obtained.

Inorganic gel aqueous solution composition

Smectite (which is the same as that used in Example 1)

35 Smectite	1.8 wt%
CHAPS (surface-active agent)	0.4 wt%

Reagent solution composition

	[Cu(bpy) ₂]Cl ₂	80 mM
	[OsCl(Him)(dmbpy) ₂]Cl ₃	3 mM
	PQQ-GDH	1000 U/ml
	BSA	5%
5	CHAPS	0.4%

Serum having four different glucose concentrations (0 mg/ml, 2 mg/ml, 4 mg/ml, and 6 mg/ml) was applied to the test piece, and color produced in the test piece was measured after 5 seconds from the application by using a reflectance measuring device (wavelength: 470 nm).

- 10 The graph in FIG. 7 shows the results. As shown in FIG. 7, the test piece produced color in accordance with the glucose concentration immediately after the application. This color (reddish brown) corresponding to the glucose concentration also was observed visually. Moreover, the color production occurred in an instant. The glucose-containing serum was
- 15 prepared in the following manner. Human blood plasma was glycolyzed completely, frozen, and melted to produce serum. Then, glucose with different concentrations as described above was added to the serum.

Example 8

- 20 A 500 mM glucose aqueous solution (10 μ l) was added to a reagent solution (100 μ l) having the following composition. Then, a change in color of the reagent solution from green (the original color) to reddish brown was observed visually within one minute. The original color of the reagent solution was made by mixing the yellow of a coenzyme (FAD) included in

- 25 Reagent solution composition

	GOD (manufactured by Sigma, specific activity 209 U/mg)	50 mg/ml
	[Cu(bpy) ₂]Cl ₂	40 mM
	PIPES (pH 7.0)	50 mM
30	CHAPS	0.1 wt%

Example 9

- 35 A 500 mM glucose aqueous solution (10 μ l) was added to a reagent solution (100 μ l) having the following composition. Then, a change in color of the reagent solution from green (the original color) to reddish brown was observed visually within 5 seconds. The original color of the reagent solution was made by mixing the yellow of a coenzyme (FAD) included in GOD and the blue of copper.

Reagent solution composition

GOD (manufactured by Sigma, specific activity 209 U/mg)

		50 mg/ml
	$[\text{Cu}(\text{bpy})_2]\text{Cl}_2$	40 mM
5	$[\text{OsCl}(\text{Him})(\text{dmbpy})_2]\text{Cl}_2$	0.3 mM
	PIPES (pH 7.0)	50 mM
	CHAPS	0.1 wt%

Example 10

- 10 A copper complex was prepared by using various ligands. Copper (II) chloride and each of the following ligands were mixed at a molar ratio of 1 : 2, dissolved in purified water, and incubated for 10 minutes in a water bath at about 80°C so that the ligands were coordinated to the metal. Thus, complex solutions were obtained.

Ligand	Manufacturer	Complex
1,10-phenanthroline	Wako Pure Chemical Industries, Ltd.	$[\text{Cu}(1,10\text{-phenanthroline})_2]$
bathophenanthroline	Wako Pure Chemical Industries, Ltd.	$[\text{Cu}(\text{bathophenanthroline})_2]$
bathophenanthroline sulfonic acid disodium salt	Nacalai Tesque, Inc.	$[\text{Cu}(\text{bathophenanthroline sulfonic acid})_2]$
2,2'-bipyridyl	Wako Pure Chemical Industries, Ltd.	$[\text{Cu}(2,2'\text{-bipyridyl})_2]$
TPTZ	DOJINDO LABORATORIES	$[\text{Cu}(\text{TPTZ})_2]$
cuproin	Wako Pure Chemical Industries, Ltd.	$[\text{Cu}(\text{cuproin})_2]$

15

Example 11

- 20 A copper mixed ligand complex was prepared by using each of the following ligands and the bipyridyl compounds. Copper, each of the following ligands, and the bipyridyl compounds were mixed at a molar ratio of 1 : 2 : 1, dissolved in purified water, and incubated for 10 minutes in a water bath at about 80°C so that the ligands and the bipyridyl compounds were coordinated to the metal. Thus, complex solutions were obtained.

Ligand	Manufacturer	Complex
L-arginine	Nacalai Tesque, Inc.	[Cu(L-Arg)(bpy)]
ethylenediamine	Nacalai Tesque, Inc.	[Cu(en)(bpy)]
imidazole	Wako Pure Chemical Industries, Ltd.	[Cu(Him)(bpy)]

Example 12

- 5 An iron complex was prepared by using various ligands. Iron (III) chloride and each of the following ligands were mixed at a molar ratio of 1 : 3, dissolved in purified water, and incubated for 10 minutes in a water bath at about 80°C so that the ligands were coordinated to the metal. Thus, complex solutions were obtained.

Ligand	Manufacturer	Complex
1,10-phenanthroline	Wako Pure Chemical Industries, Ltd.	[Fe(1,10-phenanthroline) ₃]
bathophenanthroline	Wako Pure Chemical Industries, Ltd.	[Fe(bathophenanthroline) ₃]
bathophenanthroline sulfonic acid disodium salt	Nacalai Tesque, Inc.	[Fe(bathophenanthroline sulfonic acid) ₃]
2,2'-bipyridyl	Wako Pure Chemical Industries, Ltd.	[Fe(2,2'-bipyridyl) ₃]
4,4'-diamino-2,2'-bipyridyl (DA-bpy)	Arkray, Inc.	[Fe(4,4'-diamino-2,2'-bipyridyl) ₃]
TPTZ	DOJINDO LABORATORIES	[Fe(TPTZ) ₃]
PDTS	DOJINDO LABORATORIES	[Fe(PDTS) ₃]
nitroso-PSAP	DOJINDO LABORATORIES	[Fe(nitroso-PSAP) ₃]
nitroso-ESAP	DOJINDO LABORATORIES	[Fe(nitroso-ESAP) ₃]
1-nitroso-2-naphthol	KANTO KAGAKU	[Fe(1-nitroso-2-naphthol) ₃]
2-amino-4-thiazole acetic acid	Lancaster	[Fe(2-amino-4-thiazole acetic acid) ₃]
1,2-naphthoquinone-4-sulfonic acid	Nacalai Tesque, Inc.	[Fe(1,2-naphthoquinone-4-sulfonic acid) ₃]
nitro-PAPS	DOJINDO LABORATORIES	[Fe(nitro-PAPS) ₃]

Example 13

Two types of ruthenium complexes were prepared in the following manner.

5 $[\text{Ru}(\text{NH}_3)_6]$

A commercially available ruthenium complex (manufactured by Aldrich, Hexaammineruthenium (III) chloride) was dissolved in water to obtain a complex solution of $[\text{Ru}(\text{NH}_3)_6]$.

$[\text{Ru}(4,4'\text{-diamino-2,2'-bipyridyl})_3]$

10 Ligand

First, 11.8 g (63.0 mmol) of 2,2'-bipyridyl- $\text{N,N}'$ -dioxide (manufactured by Aldrich) was dissolved slowly in 120 ml of concentrated sulfuric acid cooled in an ice bath, and the solution was heated to 100°C. Then, a concentrated sulfuric acid solution (100 ml) containing 64.0 g (630
15 mmol) of potassium nitrate was slowly added dropwise and stirred for 1 hour while heating. After reaction, the solution was cooled to room temperature, poured into crushed ice, and filtered. Thus, a solid of 4,4'-dinitro-2,2'-bipyridyl- $\text{N,N}'$ -oxide was obtained. Next, 7.0 g (25 mM) of 4,4'-dinitro-2,2'-bipyridyl- $\text{N,N}'$ -oxide and 6.0 g of 10% palladium carbon were
20 suspended in ethanol (23 ml) under Ar. To this solution was added dropwise an ethanol solution (47 ml) containing 6.3 g (126 mmol) of hydrazine monohydrate, followed by refluxing for 8 hours. The solution was cooled and filtered. The filtrate was concentrated and purified by silica gel column chromatography. Thus, 4,4'-diamino-2,2'-bipyridyl was
25 obtained.

Synthesis

Ethylene glycol (10 mL) was placed in a 50 mL two-neck flask, in which DA-bpy (0.2 g) and RuCl_3 (0.1 g) were dissolved and stirred successively. The solution was heated by a mantle heater while vigorously
30 stirring under N_2 , followed by refluxing for about 4 hours.

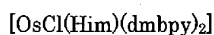
Purification

After stirring and cooling under N_2 , the solution was moved to a 100 mL round bottom flask and washed with acetone (5 mL) + diethyl ether (20 mL). This washing of the solution with acetone (5 mL) + diethyl ether (20
35 mL) was repeated until the solvent (ethylene glycol) was removed sufficiently. The target substance thus washed was dissolved in ethanol and precipitated by the addition of diethyl ether. The target substance was

filtered while washing with diethyl ether and dried under reduced pressure. Thus, a solid of $[\text{Ru}(4,4'\text{-diamino-}2,2'\text{-bipyridyl})_3]$ was obtained. This solid was dissolved in water to obtain a complex solution.

Example 14

5 Two types of osmium complexes were prepared in the following manner.

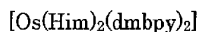


Synthesis

First, 2.00 g (4.56 mmol) of $(\text{NH}_4)_2[\text{OsCl}_6]$ (manufactured by Aldrich) and 1.68 g (9.11 mmol) of 4,4'-dimethyl-2,2'-bipyridyl (dmbpy, manufactured by Wako Pure Chemical Industries, Ltd.) were refluxed in ethylene glycol (60 ml) for 1 hour under N_2 . After cooling to room temperature, 1M sodium dithionite solution (120 ml) was added for 30 minutes, followed by cooling in an ice bath for 30 minutes. The precipitates were filtered under reduced pressure and sufficiently washed with water (500 to 1000 ml). Further, the precipitates were washed with diethyl ether two times, and then dried under reduced pressure. Thus, 1.5 to 1.7 g of $[\text{OsCl}_2(\text{dmbpy})_2]$ was obtained. Next, 1.56 g (2.60 mmol) of $[\text{OsCl}_2(\text{dmbpy})_2]$ and 0.36 g (5.2 mmol) of imidazole (Him) were refluxed in a water/methanol mixed solvent (50 ml) under N_2 for 2 hours. After cooling to room temperature, a saturated NaCl solution (300 ml) was added. The precipitates were filtered under reduced pressure, washed with a saturated NaCl solution, and dried under reduced pressure. Thus, $[\text{OsCl}(\text{Him})(\text{dmbpy})_2]\text{Cl}_2$ was obtained.

Purification

25 The $[\text{OsCl}(\text{Him})(\text{dmbpy})_2]\text{Cl}_2$ was dissolved in the smallest possible amount of acetonitrile/methanol (1 : 1 v/v) and purified by column chromatography (absorbent: activated alumina, developing solvent: acetonitrile/methanol). The solvent was evaporated, and the residue was dissolved in a small amount of acetone and reprecipitated with diethyl ether. 30 The precipitates were filtered and dried under reduced pressure, and then dissolved in water. Thus, a complex solution was obtained.



Synthesis

First, 2.00 g (4.56 mmol) of $(\text{NH}_4)_2[\text{OsCl}_6]$ and 1.68 g (9.11 mmol) of dmbpy were refluxed in ethylene glycol (60 ml) under N_2 for 1 hour. After cooling to room temperature, 1M sodium dithionite solution (120 ml) was added for 30 minutes, followed by cooling in an ice bath for 30 minutes.

The precipitates were filtered under reduced pressure and sufficiently washed with water (500 to 1000 ml). Further, the precipitates were washed with diethyl ether two times, and then dried under reduced pressure. Thus, 1.5 to 1.7 g of $[\text{OsCl}_2(\text{dmbpy})_2]$ was obtained. Next, 1.56 g (2.60 mmol) of $[\text{OsCl}_2(\text{dmbpy})_2]$ and 0.36 g (5.2 mmol) of imidazole (Him) were refluxed in a 1,2-ethanedithiol solvent (50 ml) under N_2 for 2 hours. After cooling to room temperature, a saturated NaCl solution (300 ml) was added. The precipitates were filtered under reduced pressure, washed with a saturated NaCl solution, and dried under reduced pressure. Thus, $[\text{Os}(\text{Him})_2(\text{dmbpy})_2]\text{Cl}_2$ was obtained.

Purification

The $[\text{Os}(\text{Him})_2(\text{dmbpy})_2]\text{Cl}_2$ was dissolved in the smallest possible amount of acetonitrile/methanol (1 : 1 v/v) and purified by column chromatography (absorbent: activated alumina, developing solvent: acetonitrile/methanol). The solvent was evaporated, and the residue was dissolved in a small amount of acetone and reprecipitated with diethyl ether. The precipitates were filtered and dried under reduced pressure, and then dissolved in water. Thus, a complex solution was obtained.

Example 15

Reagent solutions were prepared by mixing a complex including phenanthroline ligands in NN coordination form, an enzyme, and a buffer solution with the following compositions 1 to 6. The spectrum of each of the reagent solutions was measured and identified as a blank. Further, glucose equivalent in amount to the complex was added to each of the reagent solutions, and the spectrum was measured after the color change. FIGS. 8A to 8F show the results. The complexes prepared in the above examples were used.

Reagent solution composition 1 (FIG. 8A)

PQQ-GDH	50 U/mL
$[\text{Cu}(1,10\text{-phenanthroline})_2]$	1 mM
PIPES pH 7	50 mM
Triton X-100	0.5%

Reagent solution composition 2 (FIG. 8B)

PQQ-GDH	50 U/mL
$[\text{Fe}(1,10\text{-phenanthroline})_3]$	0.1 mM
PIPES pH 7	50 mM
Triton X-100	0.5%

Reagent solution composition 3 (FIG. 8C)

	PQQ-GDH	50 U/mL
	[Cu(bathophenanthroline) ₂]	1 mM
	PIPES pH 7	50 mM
5	Triton X-100	0.5%

(bathophenanthroline = 4,7-diphenyl phenanthroline)

Reagent solution composition 4 (FIG. 8D)

	PQQ-GDH	50 U/mL
	[Fe(bathophenanthroline) ₃]	1 mM
10	PIPES pH 7	50 mM
	Triton X-100	0.5%

(bathophenanthroline = 4,7-diphenyl phenanthroline)

Reagent solution composition 5 (FIG. 8E)

	PQQ-GDH	50 U/mL
15	[Cu(bathophenanthroline sulfonic acid) ₂]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

Reagent solution composition (FIG. 8F)

	PQQ-GDH	50 U/mL
20	[Fe(bathophenanthroline sulfonic acid) ₃]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

Example 16

Reagent solutions were prepared by mixing a complex including
 25 bipyridyl ligands in NN coordination form, an enzyme, and a buffer solution
 with the following compositions 1 to 4. The spectrum of each of the reagent
 solutions was measured and identified as a blank. Further, glucose
 equivalent in amount to the complex was added to each of the reagent
 solutions, and the spectrum was measured after the color change. FIGS.
 30 9A to 9D show the results. The complexes prepared in the above examples
 were used.

Reagent solution composition 1 (FIG. 9A)

	PQQ-GDH	50 U/mL
	[Cu(2,2'-bipyridyl) ₂]	1 mM
35	PIPES pH 7	50 mM
	Triton X-100	0.5%

Reagent solution composition 2 (FIG. 9B)

	PQQ-GDH	50 U/mL
	[Fe(2,2'-bipyridyl) ₃]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%
5	Reagent solution composition 3 (FIG. 9C)	
	PQQ-GDH	50 U/mL
	[Fe(4,4'-diamino-2,2'-bipyridyl) ₃]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%
10	Reagent solution composition 4 (FIG. 9D)	
	PQQ-GDH	50 U/mL
	[Ru(4,4'-diamino-2,2'-bipyridyl) ₃]	10 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%
15	<i>Example 17</i>	
	Reagent solutions were prepared by mixing a complex including triazine ligands in NN coordination form, an enzyme, and a buffer solution with the following compositions 1 to 3. The spectrum of each of the reagent solutions was measured and identified as a blank. Further, glucose	
20	equivalent in amount to the complex was added to each of the reagent solutions, and the spectrum was measured after the color change. FIGS. 10A to 10C show the results. The complexes prepared in the above examples were used.	
	Reagent solution composition 1 (FIG. 10A)	
25	PQQ-GDH	50 U/mL
	[Cu(TPTZ) ₂]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%
	(TPTZ = 2,4,6-tripyridyl-s-triazine)	
30	Reagent solution composition 2 (FIG. 10B)	
	PQQ-GDH	50 U/mL
	[Fe(TPTZ) ₃]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%
35	(TPTZ = 2,4,6-tripyridyl-s-triazine)	
	Reagent solution composition 3 (FIG. 10C)	
	PQQ-GDH	50 U/mL

[Fe(PDTS) ₃]	1 mM
PIPES pH 7	50 mM
Triton X-100	0.5%

(PDTS = 3-(2-pyridyl)-5,6-bis(4-sulfophenyl)-1,2,4-triazine)

5 *Example 18*

A reagent solution was prepared by mixing a complex including biquinoline ligands in NN coordination form, an enzyme, and a buffer solution with the following composition. The spectrum of the reagent solution was measured and identified as a blank. Further, glucose equivalent in amount to the complex was added to the reagent solution, and the spectrum was measured after the color change. FIG. 11 shows the results. The complex prepared in the above examples was used.

Reagent solution composition

PQQ-GDH	50 U/mL
[Cu(cuproin) ₂]	1 mM
PIPES pH 7	50 mM
Triton X-100	0.5%

(cuproin = 2,2'-biquinoline)

Example 19

20 A reagent solution was prepared by mixing a complex including pyridylazo ligands in NN coordination form, an enzyme, and a buffer solution with the following composition. The spectrum of the reagent solution was measured and identified as a blank. Further, glucose equivalent in amount to the complex was added to the reagent solution, and the spectrum was measured after the color change. FIG. 12 shows the results. The complex prepared in the above examples was used.

Reagent solution composition

PQQ-GDH	50 U/mL
[Fe(nitro-PAPS) ₃]	0.02 mM
PIPES pH 7	50 mM
Triton X-100	0.5%

(nitro-PAPS =

2-(5-nitro-2-pyridylazo)-5-[N-n-propyl-N-(3-sulfopropyl)aminophenol])

Example 20

35 Reagent solutions were prepared by mixing a complex including ligands in NO coordination form, an enzyme, and a buffer solution with the following compositions 1 to 3. The spectrum of each of the reagent

solutions was measured and identified as a blank. Further, glucose equivalent in amount to the complex was added to each of the reagent solutions, and the spectrum was measured after the color change. FIGS. 13A to 13C show the results. The complexes prepared in the above

5 examples were used.

Reagent solution composition 1 (FIG. 13A)

	PQQ-GDH	50 U/mL
	[Fe(nitroso-PSAP) ₃]	0.05 mM
	PIPES pH 7	50 mM
10	Triton X-100	0.5%
	(nitroso-PSAP =	

2-nitroso-5-[N-n-propyl-N-(3-sulfopropyl)aminophenol])

Reagent solution composition 2 (FIG. 13B)

	PQQ-GDH	50 U/mL
15	[Fe(nitroso-ESAP) ₃]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

(nitroso-ESAP = 2-nitroso-5-[N-ethyl-N-(3-sulfopropyl)aminophenol])

Reagent solution composition 3 (FIG. 13C)

20	PQQ-GDH	50 U/mL
	[Fe(1-nitroso-2-naphthol) ₃]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

Example 21

25 A reagent solution was prepared by mixing a complex including ligands in NS coordination form, an enzyme, and a buffer solution with the following composition. The spectrum of the reagent solution was measured and identified as a blank. Further, glucose equivalent in amount to the complex was added to the reagent solution, and the spectrum was measured

30 after the color change. FIG. 14 shows the results. The complex prepared in the above examples was used.

Reagent solution composition

	PQQ-GDH	50 U/mL
	[Fe(2-amino-4-thiazoleacetic acid) ₃]	1 mM
35	PIPES pH 7	50 mM
	Triton X-100	0.5%

Example 22

A reagent solution was prepared by mixing a complex including ligands in OO coordination form, an enzyme, and a buffer solution with the following composition. The spectrum of the reagent solution was measured and identified as a blank. Further, glucose equivalent in amount to the
 5 complex was added to the reagent solution, and the spectrum was measured after the color change. FIG. 15 shows the results. The complex prepared in the above examples was used.

Reagent solution composition

	PQQ-GDH	50 U/mL
10	[Fe(1,2-naphthoquinone-4-sulfonic acid) ₃]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

Example 23

Reagent solutions were prepared by mixing a mixed ligand complex,
 15 an enzyme, and a buffer solution with the following compositions 1 to 5. The spectrum of each of the reagent solutions was measured and identified as a blank. Further, glucose equivalent in amount to the complex was added to each of the reagent solutions, and the spectrum was measured after the color change. FIGS. 16A to 16E show the results. The complexes
 20 prepared in the above examples were used.

Reagent solution composition 1 (FIG. 16A)

	PQQ-GDH	50 U/mL
	[OsCl(Him)(dmbpy) ₂]	0.1 mM
	PIPES pH 7	50 mM
25	Triton X-100	0.5%

(Him = imidazole)

(dmbpy = 4,4'-dimethyl-2,2'-bipyridyl)

Reagent solution composition 2 (FIG. 16B)

	PQQ-GDH	50 U/mL
30	[Os(Him) ₂ (dmbpy) ₂]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

Reagent solution composition 3 (FIG. 16C)

	PQQ-GDH	50 U/mL
35	[Cu(L-Arg) ₂ (bpy)]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

(L-Arg = L-arginine)

(bpy = 2,2'-bipyridyl)

Reagent solution composition 4 (FIG. 16D)

	PQQ-GDH	50 U/mL
5	[Cu(en) ₂ (bpy)]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

(en = ethylenediamine)

(bpy = 2,2'-bipyridyl)

10 Reagent solution composition 5 (FIG. 16E)

	PQQ-GDH	50 U/mL
	[Cu(Him) ₂ (bpy)]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

15 *Example 24*

Reagent solutions were prepared by mixing a complex, an enzyme (glucose oxidase (GOD) or pyruvate oxidase), and a buffer solution with the following compositions 1 and 2. The spectrum of each of the reagent solutions was measured and identified as a blank. Further, glucose or
20 pyruvic acid equivalent in amount to the complex was added to each of the reagent solutions, and the spectrum was measured after the color change. FIGS. 17A and 17B show the results. The complexes prepared in the above examples were used.

Reagent solution composition 1 (FIG. 17A)

25	GOD	100 U/mL
	[Cu(2,2'-bipyridyl) ₂]	1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

Reagent solution composition 2 (FIG. 17B)

30	pyruvate oxidase	100 U/mL
	[OsCl(Him)(dmbpy) ₂]	0.1 mM
	PIPES pH 7	50 mM
	Triton X-100	0.5%

(Him = imidazole)

35 (dmbpy = 4,4'-dimethyl-2,2'-bipyridyl)

Example 25

A reagent solution was prepared with the following composition.

Moreover, the following enzyme solutions 1, 2, and 3 were prepared. Then, 10 μ L of glucose aqueous solution (with concentrations of 0, 10, 20, and 30 mM and final concentrations of 0, 0.1, 0.2, and 0.3 mM, respectively) and 500 μ L of the reagent solution were mixed in a disposcell having an optical path length of 10 mm, to which 500 μ L of each of the enzyme solutions was added to cause a reaction between the solutions. The absorbance change was measured for 50 seconds with a spectrophotometer (wavelength: 600 nm). FIGS. 18A, 18B, and 18C show the results. As shown in FIGS. 18A, 18B, and 18C, the reaction rate increased with the amount of enzyme.

When the enzyme activity was 1000 U/mL, the reaction came to an end in about 5 seconds. It is possible to quantify the glucose concentration by sampling signals near 5 seconds, at which the reaction reaches the end. The slope of the graphs from the beginning to the end of the reaction also can be used to quantify the glucose concentration.

15 Reagent solution composition

Cu(PDTS) ₂	1 mM
PIPES pH 7	50 mM
Triton X-100	0.5%

Enzyme solution 1 (FIG. 18A)

20 PQQ-GDH 111 U/mL

Enzyme solution 2 (FIG. 18B)

PQQ-GDH 333 U/mL

Enzyme solution 3 (FIG. 18C)

PQQ-GDH 1000 U/mL

25

Industrial Applicability

As described above, a colorimetric method of the present invention can perform simple and reliable analysis in a short time.

CLAIMS

1. A colorimetric method including:
allowing and oxidoreductase to act on an analyte and a color-changeable
5 substance that changes color by transferring an electron; and
performing a qualitative or quantitative analysis of the analyte by
measuring color produced in the color-changeable substance due to electron
transfer from the analyte to the color-changeable substance.
- 10 2. The colorimetric method according to claim 1, wherein the color-
changeable substance that changes color by transferring an electron is a
transition metal complex.
3. The colorimetric method according to claim 2, wherein the transition
15 metal complex is at least one complex selected from the group consisting of a
copper complex, an iron complex, a ruthenium complex, and an osmium
complex.
4. The colorimetric method according to claim 2 or 3, wherein a
20 coordinating atom of a ligand in the transition metal complex is at least one
selected from the group consisting of nitrogen, oxygen, and sulfur.
5. The colorimetric method according to any one of claims 2 to 4, wherein
the ligand in the transition metal complex is selected from the group consisting
25 of ammonia, a bipyridyl compound, an imidazole compound, a phenanthroline
compound, an ethylenediamine compound, amino acids, a triazine compound, a
biquinoline compound, a pyridylazo compound, a nitroso compound, an oxine
compound, a benzothiazole compound, an acetylacetone compound, an
anthraquinone compound, a xanthene compound, oxalic acid,
30 4,4'-dimethyl-2,2'-bipyridyl, 4,4'-diphenyl-2,2'-bipyridyl,
4,4'-diamino-2,2'-bipyridyl, 4,4'-dihydroxy-2,2'-bipyridyl,
4,4'-dicarboxy-2,2'-bipyridyl, 4,4'-dibromo-2,2'-bipyridyl,
5,5'-dimethyl-2,2'-bipyridyl, 5,5'-diphenyl-2,2'-bipyridyl,
5,5'-diamino-2,2'-bipyridyl, 5,5'-dihydroxy-2,2'-bipyridyl,

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- 5,5'-dicarboxy-2,2'-bipyridyl, 5,5'-dibromo-2,2'-bipyridyl, 4-methyl-imidazole, 4-phenyl-imidazole, 4-amino-imidazole, 4-hydroxy-imidazole, 4-carboxy-imidazole, 4-bromo-imidazole, 1,10-phenanthroline, bathophenanthroline, bathophenanthroline sulfonic acid, 2,2'-bipyridyl,
- 5 4'-diamino-2,2'-bipyridyl, 2,4,6-tripyridyl-S-triazine, 3-(2-pyridyl)-5,6-bis(4-sulfophenyl)-1,2,4-triazine, 2,2'-biquinoline2-(5-nitro-2-pyridylazo)-5-[N-n-propyl-N-(3-sulfopropyl) amino] phenol, 2-nitroso-5-[N-n-propyl-N-(3-sulfopropyl) amino] phenol, 2-nitroso-5-[N-ethyl-N-(3-sulfopropyl) amino] phenol, 1-nitroso-2-naphthol,
- 10 2-amino-4-thiazole acetic acid, 1,2-naphthoquinone-4-sulfonic acid, 4,4'-dimethyl-2,2'-bipyridyl, and 4,4'-dimethyl-2,2'-bipyridyl.
6. The colorimetric method according to claim 5, wherein at least one hydrogen atom that occupies a position other than a coordination position of the
- 15 ligand is substituted.
7. The colorimetric method according to claim 6, wherein at least one hydrogen atom that occupies a position other than a coordination position of the ligand is substituted by at least one selected from the group consisting of an
- 20 alkyl group, an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group, a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro group, a nitroso group, a primary amine, a secondary amine, a tertiary amine, an amino group, an acyl group, an amido group, and a halogen group.
- 25
8. The colorimetric method according to any one of claim 2 to 7, wherein the transition metal complex includes two or more types of ligands.
9. The colorimetric method according to any preceding claim, wherein the
- 30 oxidoreductase is a dehydrogenase or an oxidase.
10. The colorimetric method according to any preceding claim, wherein the analyte is glucose, cholesterol, uric acid, pyruvic acid, or lactic acid, and the

oxidoreductase is a dehydrogenase or an oxidase that corresponds to the respective analyte.

11. A reagent used for the colorimetric method according to claim 1,
5 including:

an oxidoreductase; and

a color-changeable substance that changes color by transferring an electron.

12. The reagent according to claim 11, wherein the color-changeable substance that changes color by transferring an electron is a transition metal complex.

13. The reagent according to claim 12, wherein the transition metal complex
15 is at least one complex selected from the group consisting of a copper complex, an iron complex, a ruthenium complex, and an osmium complex.

14. The reagent according to claim 11 or 12, wherein a coordinating atom of a ligand in the transition metal complex is at least one selected from the group
20 consisting of nitrogen, oxygen, and sulfur.

15. The reagent according to any one of claims 12 to 14, wherein the ligand in the transition metal complex is selected from the group consisting of ammonia, a bipyridyl compound, an imidazole compound, a phenanthroline
25 compound, an ethylenediamine compound, amino acids, a triazine compound, a biquinoline compound, a pyridylazo compound, a nitroso compound, an oxine compound, a benzothiazole compound, an acetylacetone compound, an anthraquinone compound, a xanthene compound, oxalic acid,
4,4'-dimethyl-2,2'-bipyridyl, 4,4'-diphenyl-2,2'-bipyridyl,
30 4,4'-diamino-2,2'-bipyridyl, 4,4'-dihydroxy-2,2'-bipyridyl,
4,4'-dicarboxy-2,2'-bipyridyl, 4,4'-dibromo-2,2'-bipyridyl,
5,5'-dimethyl-2,2'-bipyridyl, 5,5'-diphenyl-2,2'-bipyridyl,
5,5'-diamino-2,2'-bipyridyl, 5,5'-dihydroxy-2,2'-bipyridyl,
5,5'-dicarboxy-2,2'-bipyridyl, 5,5'-dibromo-2,2'-bipyridyl, 4-methyl-imidazole,

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- 4-phenyl-imidazole, 4-amino-imidazole, 4-hydroxy-imidazole,
4-carboxy-imidazole, 4-bromo-imidazole, 1,10-phenanthroline,
bathophenanthroline, bathophenanthroline sulfonic acid, 2,2'-bipyridyl,
4'-diamino-2,2'-bipyridyl, 2,4,6-tripyridyl-S-triazine,
- 5 3-(2-pyridyl)-5,6-bis(4-sulfophenyl)-1,2,4-triazine,
2,2'-biquinoline-2-(5-nitro-2-pyridylazo)-5-[N-n-propyl-N-(3-sulfopropyl) amino]
phenol, 2-nitroso-5-[N-n-propyl-N-(3-sulfopropyl) amino] phenol,
2-nitroso-5-[N-ethyl-N-(3-sulfopropyl) amino] phenol, 1-nitroso-2-naphthol,
2-amino-4-thiazole acetic acid, 1,2-naphthoquinone-4-sulfonic acid,
- 10 4,4'-dimethyl-2,2'-bipyridyl, and 4,4'-dimethyl-2,2'-bipyridyl.
16. The reagent according to claim 15, wherein at least one hydrogen atom
that occupies a position other than a coordination position of the ligand is
substituted.
- 15
17. The reagent according to claim 16, wherein at least one hydrogen atom
that occupies a position other than a coordination position of the ligand is
substituted by at least one selected from the group consisting of an alkyl group,
an aryl group, an allyl group, a phenyl group, a hydroxyl group, an alkoxy group,
20 a carboxyl group, a carbonyl group, a sulfone group, a sulfonyl group, a nitro
group, a nitroso group, a primary amine, a secondary amine, a tertiary amine,
an amino group, an acyl group, an amido group, and a halogen group.
18. The reagent according to any one of claims 12 to 17, wherein the
25 transition metal complex includes two or more types of ligands.
19. The reagent according to any one of claims 11 to 18, wherein the
oxidoreductase is a dehydrogenase or an oxidase.
- 30 20. The reagent according to any one of claims 11 to 19, wherein the analyte
is glucose, cholesterol, uric acid, pyruvic acid, or lactic acid, and the
oxidoreductase is a dehydrogenase or an oxidase that corresponds to the
respective analyte.

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21. A test piece including the reagent according to claim 11, and a carrier.
22. The test piece according to claim 21, further including an inorganic gel.
- 5 23. A colormetric method, substantially as hereinbefore described with reference to the accompanying drawings.
24. A colorimetric method, substantially as hereinbefore described with reference to any one of the Examples.
- 10 25. A reagent used for a colorimetric method according to claim 1, substantially as hereinbefore described with reference to the accompanying drawings.
- 15 26. A reagent used for a colorimetric method according to claim 1, substantially as hereinbefore described with reference to any one of the Examples.

20 Date: 17 March, 2005

Phillips Ormonde & Fitzpatrick

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Arkray, Inc.

David B Fitzpatrick

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Fig.1

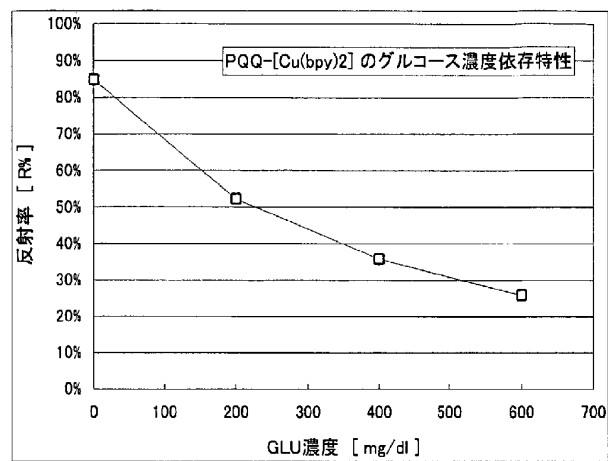


Fig. 2

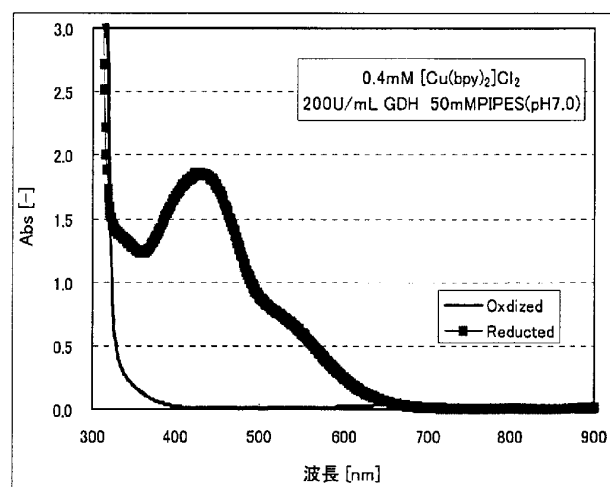


Fig.3

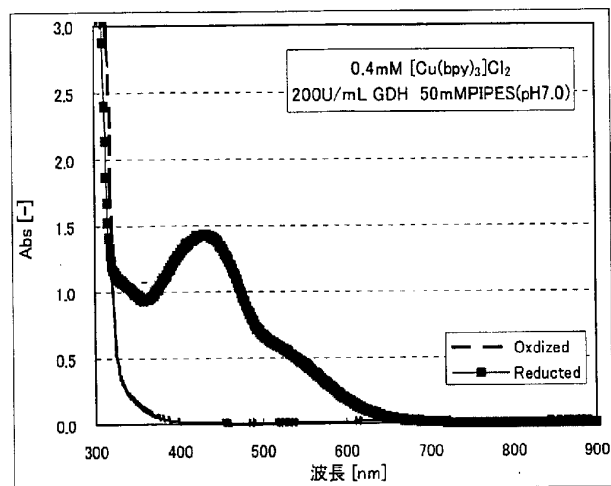


Fig.4

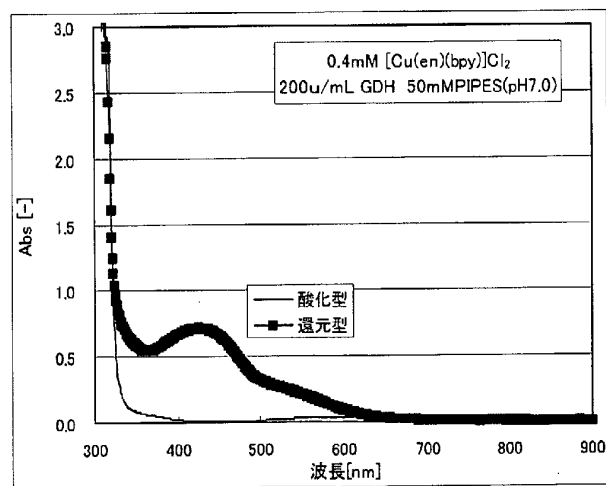


Fig.5

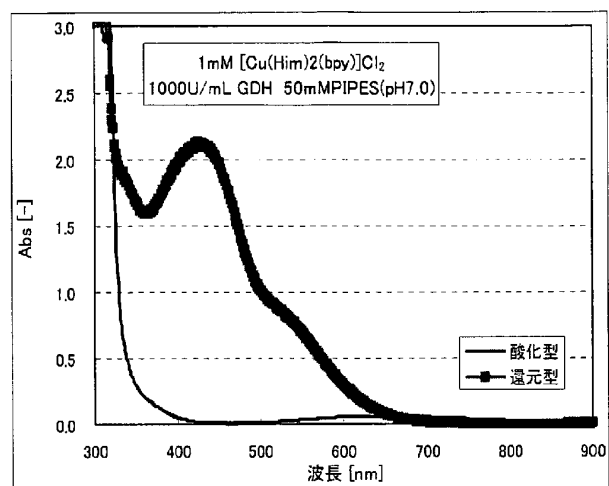
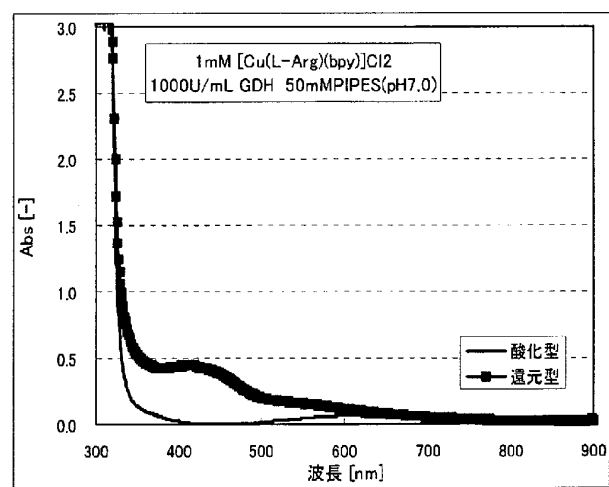


Fig.6



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Fig. 7

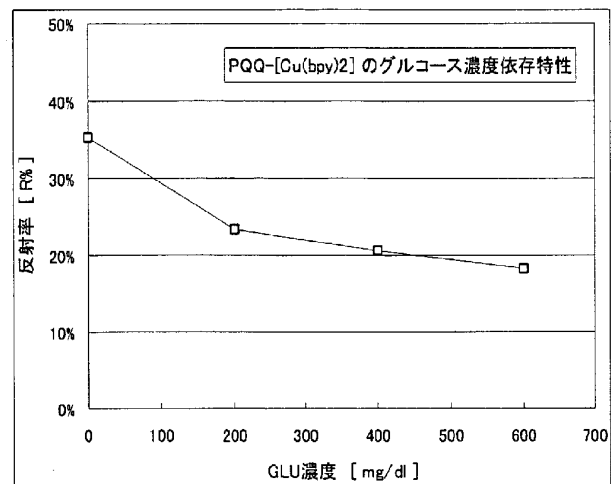


Fig.8A

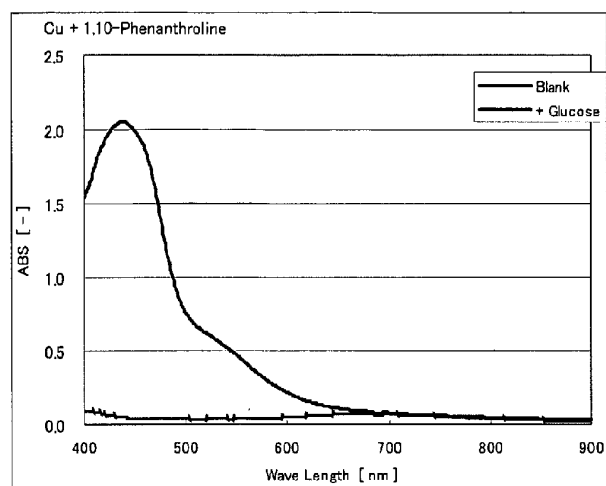


Fig.8B

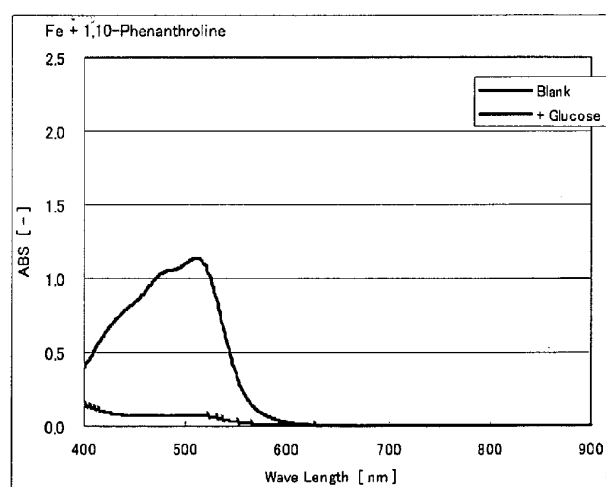


Fig.8C

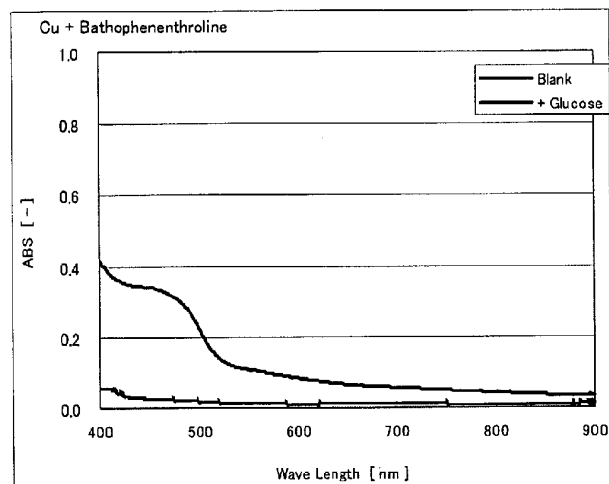


Fig.8D

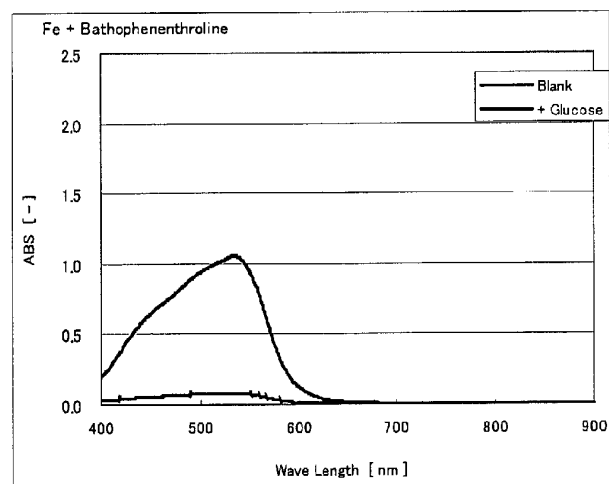


Fig.8E

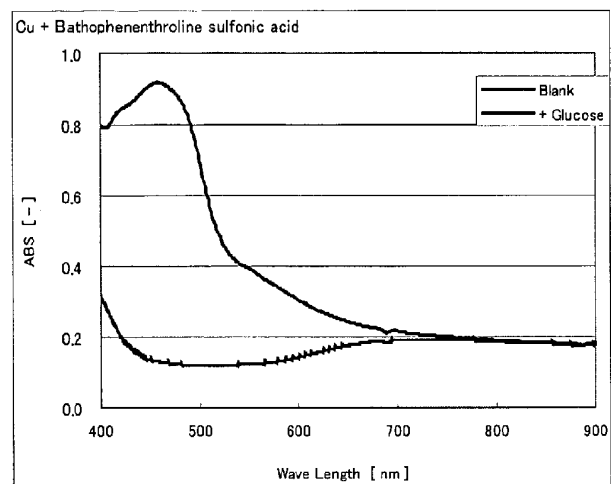


Fig.8F

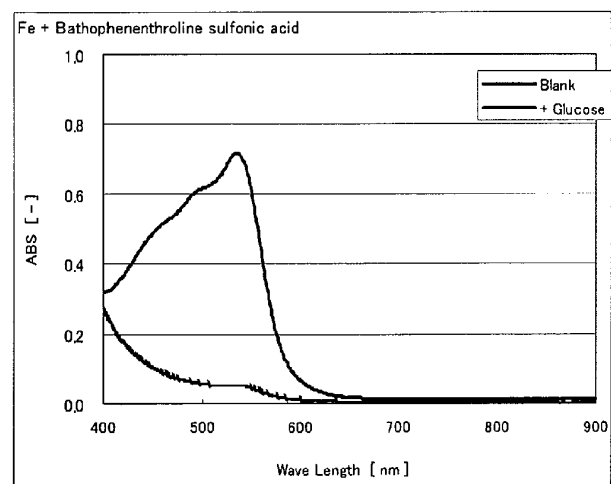


Fig.9A

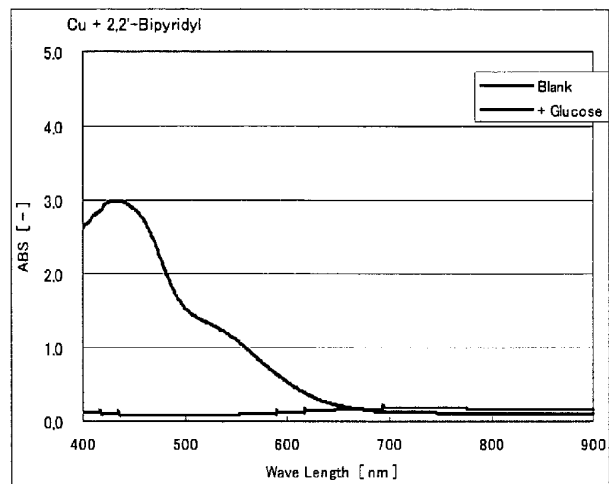
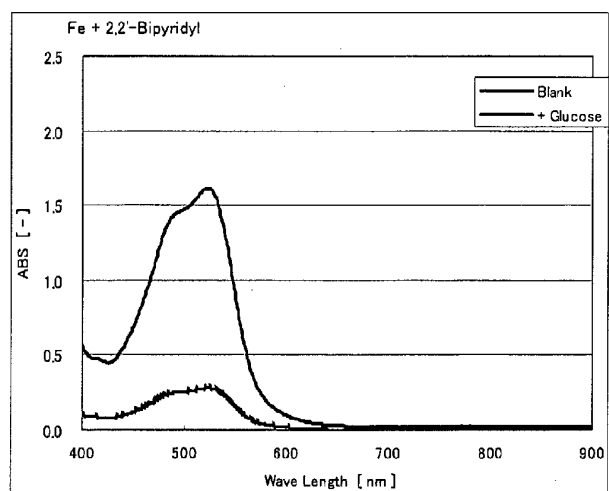


Fig.9B



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Fig.9C

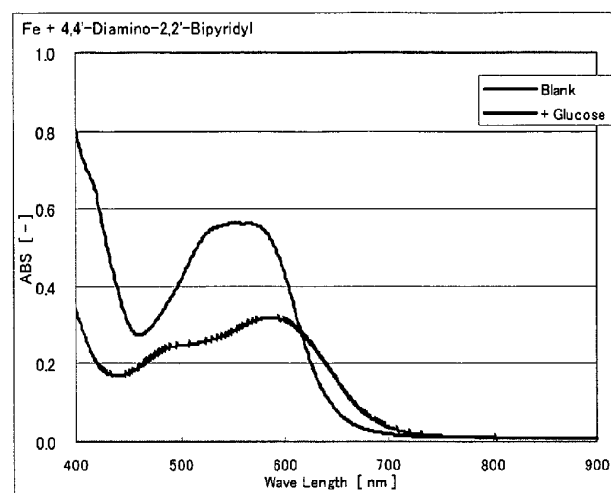


Fig.9D

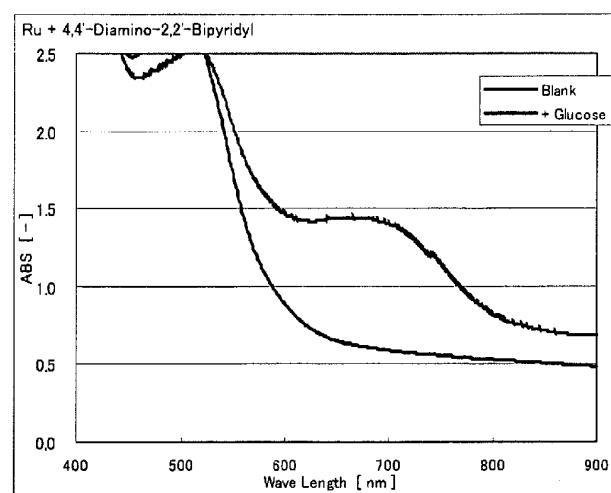


Fig.10A

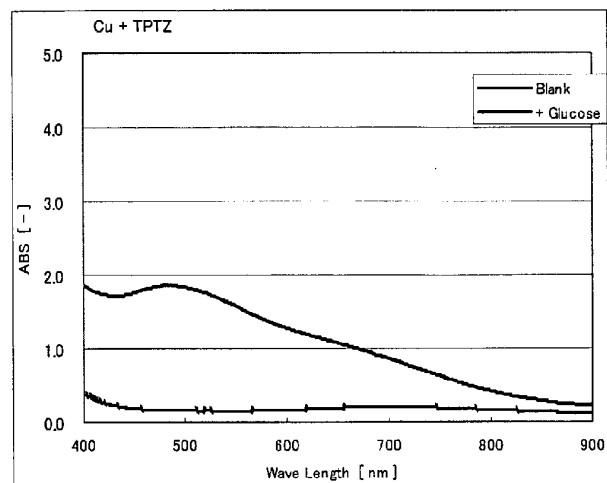


Fig.10B

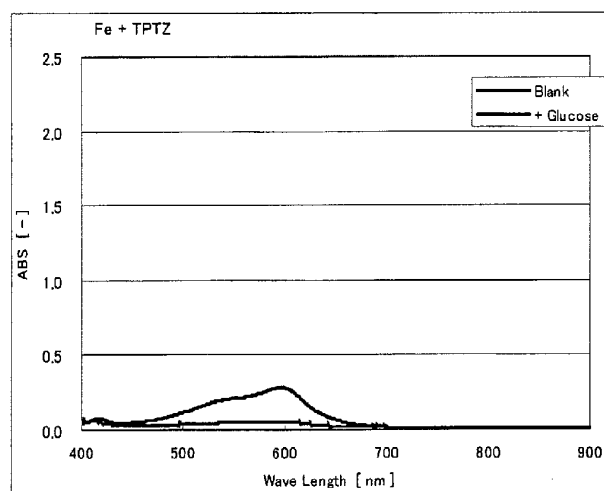


Fig.10C

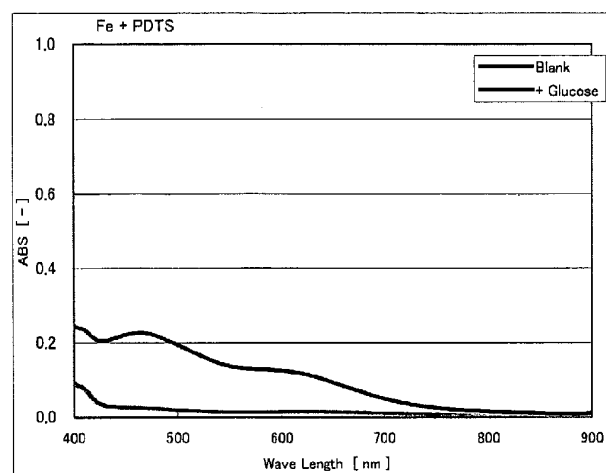


Fig.11

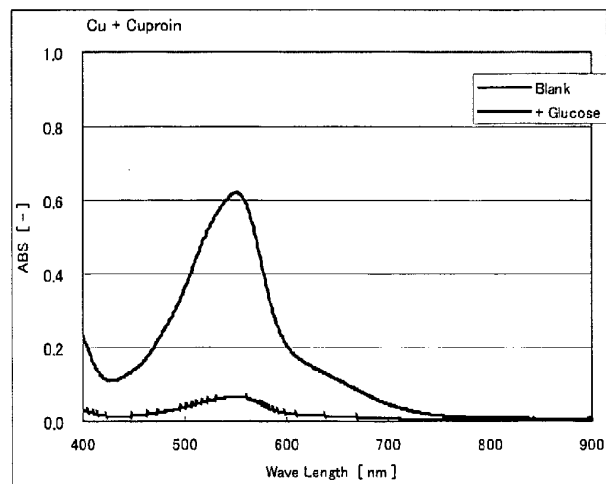


Fig.12

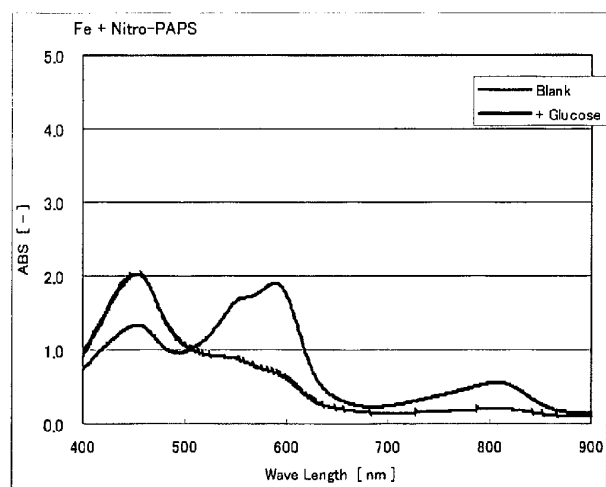


Fig.13A

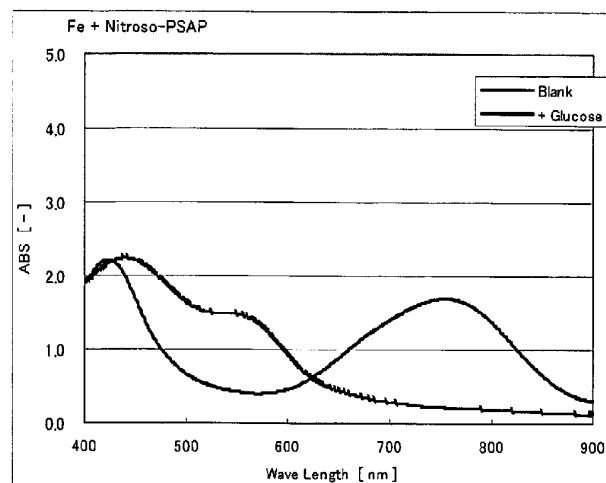


Fig.13B

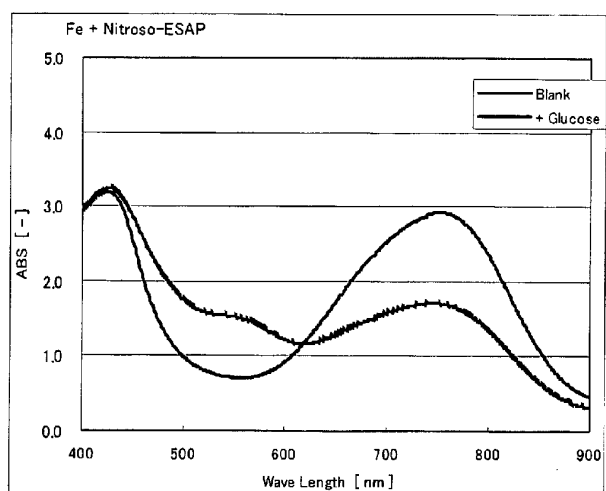


Fig.13C

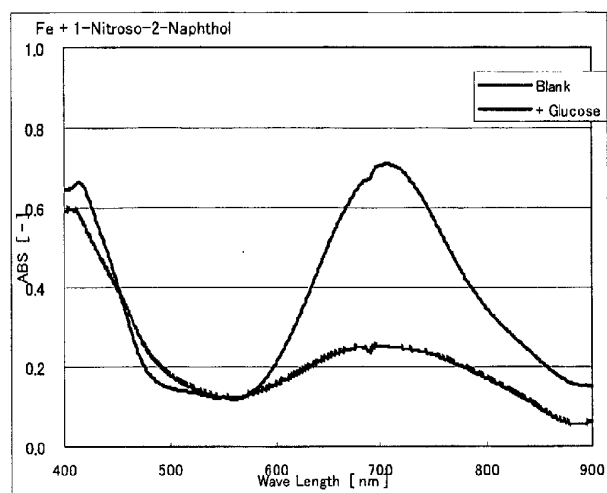


Fig.14

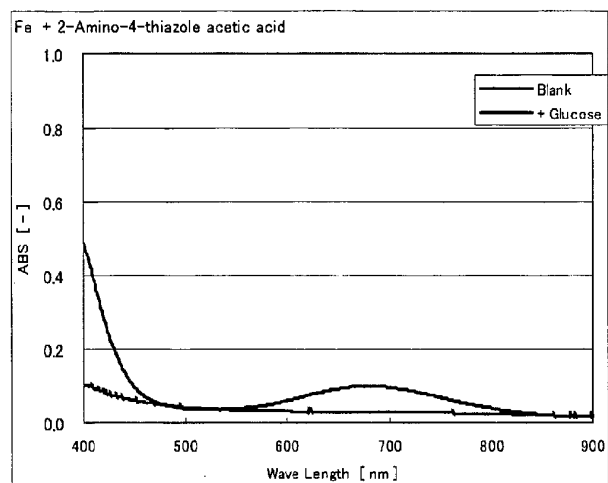


Fig.15

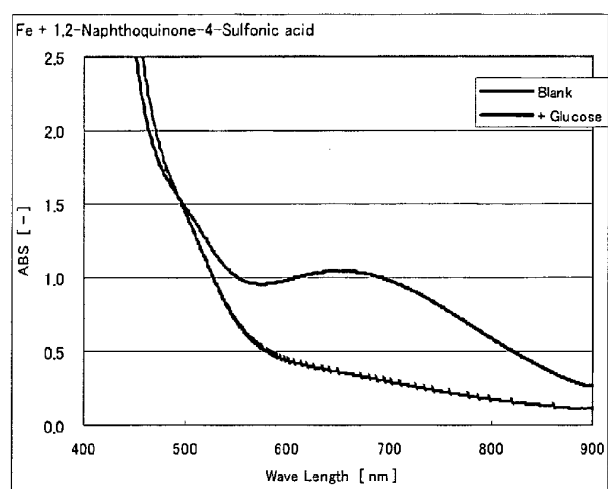


Fig.16A

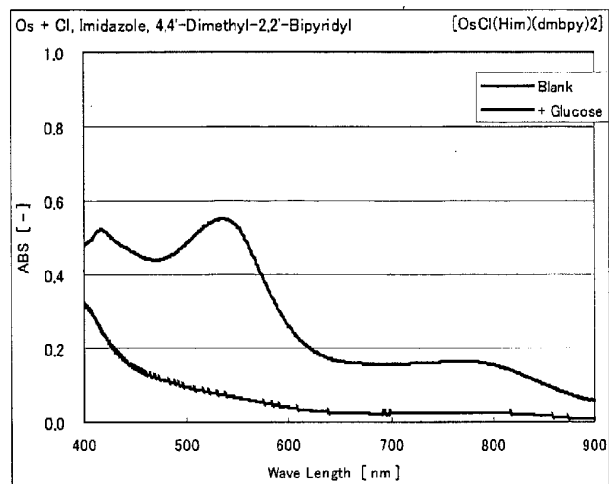
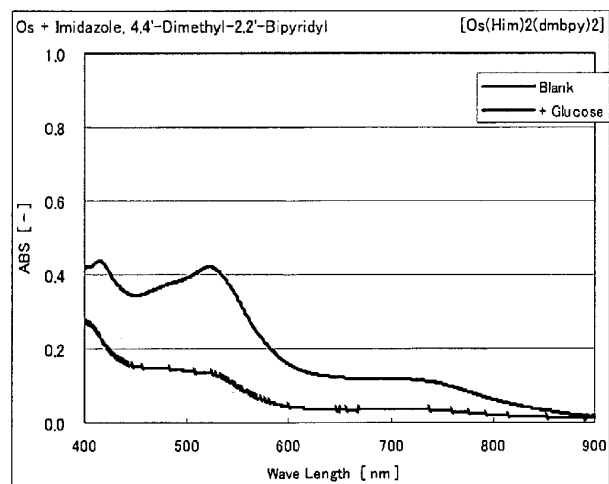


Fig.16B



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Fig.16C

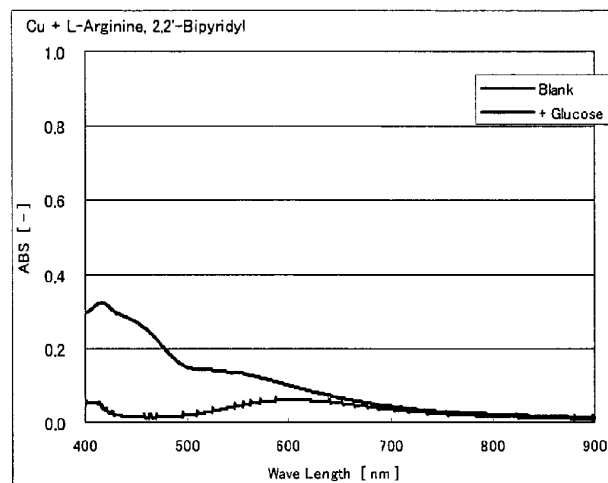
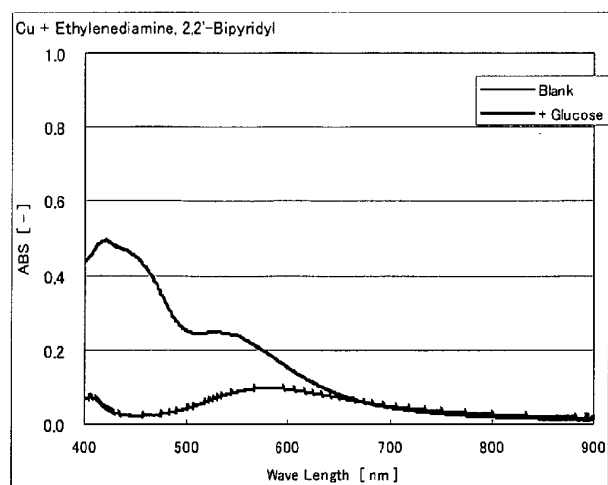


Fig.16D



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Fig.16E

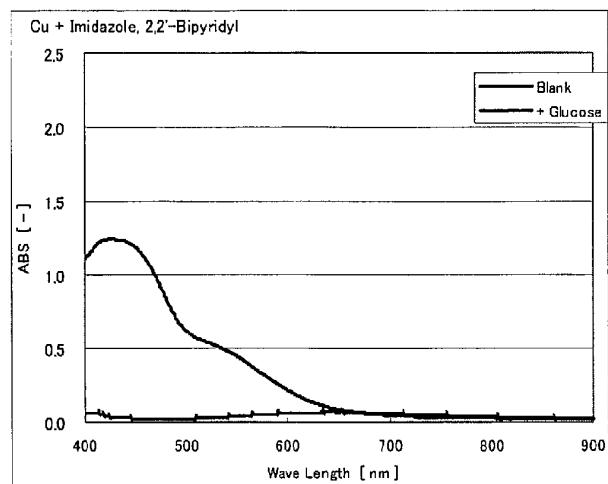


Fig.17A

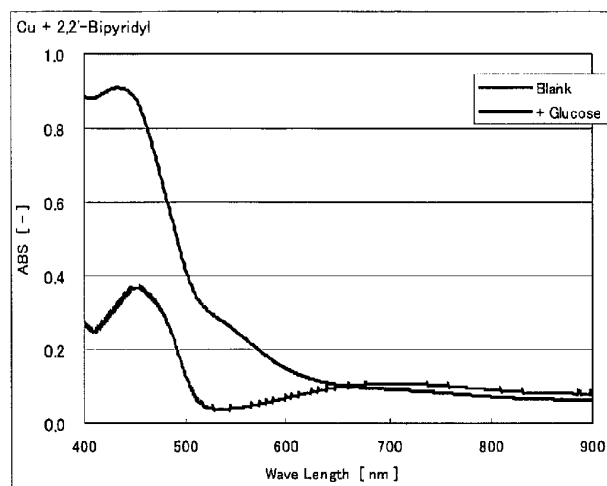


Fig.17B

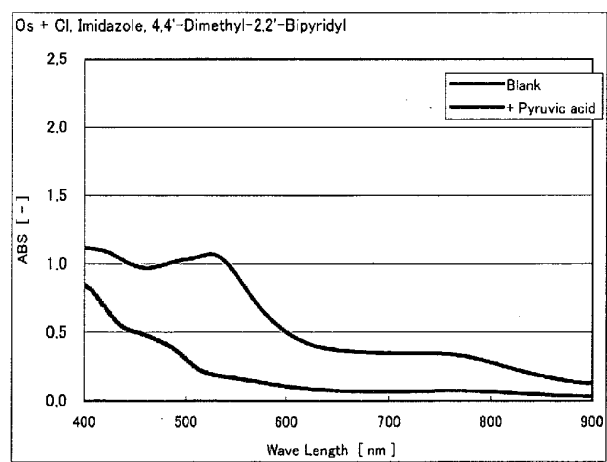


Fig.18A

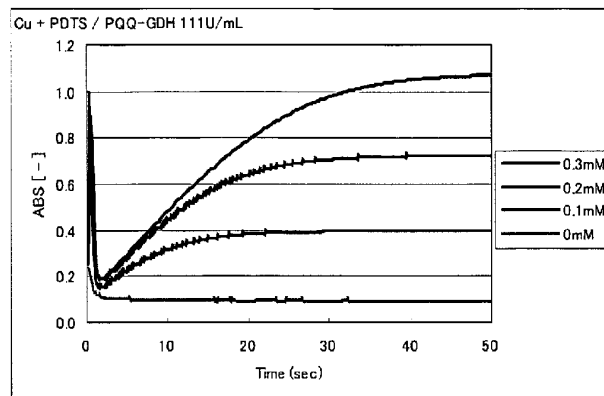


Fig.18B

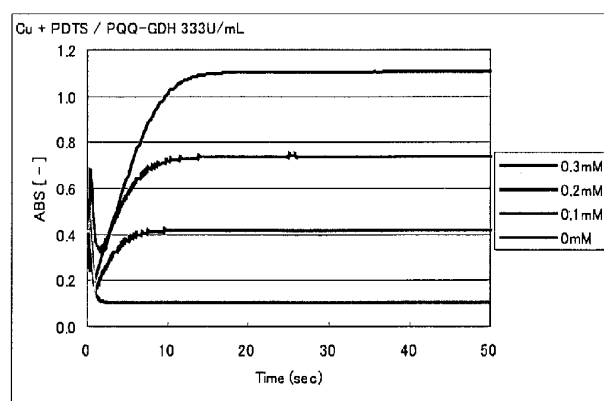


Fig.18C

