[0009] Electrochemical generation of hydrogen has focused on water electrolysis. In water electrolysis, water is split into hydrogen gas and oxygen gas. Water electrolysis is an extremely attractive process for producing hydrogen because it utilizes water, a readily available and renewal source material, and generates no harmful by-products. Water electrolysis can also be conducted at room temperature, rather than at the high temperatures required for the common, cost-effective chemical feedstocks. Although tremendous effort has been directed at achieving water electrolysis, the method has not been widely used in practice because high expenditures of electrical energy are required to effect water electrolysis. The water electrolysis reaction requires a high minimum voltage to initiate and an even higher voltage to achieve practical rates of hydrogen production. The high voltage leads to high electrical energy costs for the water electrolysis reaction and has inhibited its widespread use.

[0010] It is evident that a need exists for producing hydrogen in an efficient, economically feasible, and environmentally friendly way. It is desirable to have a process for producing hydrogen that operates at or near room temperature with minimal energy consumption. It is also desirable to have a process for producing hydrogen that avoids or minimizes the generation of environmentally harmful gases as by-products. Discovery of an acceptable process for producing hydrogen would greatly advance the cause of achieving a clean-burning economy based on hydrogen. Convenient access to hydrogen fuel, coupled to efficient technologies such as fuel cells for extracting energy from hydrogen, offers the potential to greatly reduce our current dependence on fossil fuels.

SUMMARY OF THE INVENTION

[0011] There is disclosed herein a process for producing hydrogen gas through the electrolysis of organic substances. The electrolysis process comprises the step of applying a voltage to an solution that includes an oxidizable organic substance. In addition to the organic substance, the electrolyte solution may include water, a base and/or an acid. The applied voltage effects reaction of the organic substance to produce hydrogen gas. In the absence of a base, the organic substance reacts primarily with water in an electrolysis reaction to produce hydrogen gas and carbon dioxide gas as a by-product. In the presence of a base, the organic substance reacts primarily with hydroxide ion to produce hydrogen gas along with bicarbonate ion and/or carbonate ion as by-products. Inclusion of a base provides for hydrogen production without generation of a greenhouse gas and without the need to separate hydrogen from other gas phase products. The electrolytic reaction can be run at room temperature. The hydrogen gas produced in the electrolytic reaction can be delivered to a hydrogen-based energy or storage device such as hydrogen storage alloy or used as a fuel.

[0012] A wide variety of organic substances are suitable for the present invention. In a preferred embodiment, the organic substance is more readily oxidized than water. Representative organic substances that produce hydrogen according to the instant invention include hydrocarbons, alcohols, aldehydes, sugars, ketones, carboxylic acids and ethers. Metal hydroxides are the preferred bases. In a particularly preferred embodiment of the present invention, hydrogen gas is produced from the reaction of methanol with potassium hydroxide in aqueous solution in an electrochemical reaction cell that includes Pt/C electrodes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] **FIG. 1**. Current as a function of voltage applied to electrochemical cells used to effect electrolysis of methanol in water in the presence of sulfuric acid and electrolysis of water in the presence of sulfuric acid.

[0014] **FIG. 2**. Current as a function of voltage applied to electrochemical cells used to effect electrolysis of methanol in water in the presence of potassium hydroxide and electrolysis of water in the presence of potassium hydroxide.

[0015] **FIG. 3**. Current as a function of voltage applied to electrochemical cells used to effect electrolysis of methanol in water in the presence of potassium hydroxide (9 M) and electrolysis of water in the presence of potassium hydroxide (12 M) at 23° C. and 60° C.

[0016] **FIG. 4**. Current as a function of voltage applied to electrochemical cells used to effect electrolysis of methanol in the presence of potassium hydroxide (6.4 M) without intentional inclusion of water at 38° C. and 60° C.

DETAILED DESCRIPTION OF THE INVENTION

[0017] The instant invention provides a method for efficiently producing hydrogen gas (H_2) from organic substances. The method of the instant invention subjects an organic substance to an electrolysis reaction in the presence of water in an acidic solution or in the presence of a base. The electrolysis reaction includes applying a potential to an electrochemical cell that contains the organic substance in order to effect a reaction that liberates hydrogen gas. An advantage of the instant invention is that it permits the production of hydrogen at room temperature from readily available organic substances.

[0018] Conceptually, the production of hydrogen from water is an ideal method for obtaining hydrogen. The underlying reaction for the production of hydrogen from water is the following reaction (1):

$$H_2O_{(l)} \rightleftharpoons H_{2(g)} + \tfrac{1}{2}O_{2(g)} \quad (1)$$

[0019] This reaction is a desirable approach for producing hydrogen because water is a widely available starting material and oxygen gas is an inert by-product. The drawback associated with the reaction is that it is not thermodynamically spontaneous at room temperatures and consequently does not proceed unless external energy is applied. The external energy may be provided in the form of heat or electrical potential. The practical difficulty in obtaining hydrogen from water is the high required energy expenditure. If energy in the form of heat is provided, the required temperatures are impractically high. Similarly, if electrical energy is provided, the required potentials are high and costly to maintain.

[0020] In order to appreciate the magnitude of the energy expenditure required to obtain hydrogen from water, we consider the water electrolysis reaction. In water electrolysis, energy in the form of electrical energy is applied to water in order to induce the production of hydrogen according to the foregoing reaction (1). When effected by an electrical